COMPARISON OF EFFECTIVENESS OF PHONOLOGICAL AND WHOLE-WORD TREATMENT PROGRAMMES WITHIN TWO DYSLEXIA SUBTYPES

by

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Abstract

This thesis compares the effectiveness of two reading treatment programmes, each developed to address the key difficulties of two subtypes of developmental dyslexia - phonological and surface dyslexia, respectively. Previous cognitive neuropsychological research has commonly administered a single tailored treatment programme to each individual. However, this research administers both programmes to individuals from each subtype, and compares their effectiveness.

In Experiment 1, a large group of reading-delayed children was screened, and, using Coltheart and Leahy's (1996) criteria, three children were identified as surface dyslexic and seven as phonological dyslexic. All were aged between 9 and 13 years. Following completion of a range of background tests to assess cognitive abilities potentially correlated with dyslexia, each child received two treatment programmes: 1) a phonologically-based programme training grapheme-to-phoneme correspondences (based on Broom and Doctor, 1995b) and 2) a whole-word programme (specifically designed for the current research), with pre- and post-tests throughout. Results indicated that all children significantly improved their reading of the trained words following both training programmes, regardless of subtype. For both subtypes, generalisation to untrained words was observed following the Phonological Programme, but not the Whole-word Programme. In Experiment 2, a second, more case-based investigation was conducted, focussing on one phonological dyslexic and one surface dyslexic, who were selected following extensive screening. Both were aged 10 years 11 months. Experiment 2 also examined the effectiveness of specific whole-word techniques. Results indicated a clear distinction between the responsiveness of the two participants, with each favouring their target treatment programme: the Phonological Programme was more effective for the phonological dyslexic than the Whole-word Programme, and vice versa for the surface dyslexic. The implications are discussed, with particular reference to suggestions for remediating reading disorders.

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Chapter 1: Introduction

> "Children deprived of words become school dropouts; dropouts deprived of hope behave delinquently. Amateur censors blame delinquency on reading immoral books and magazines, when in fact, the inability to read anything is the basic trouble."
> Peter S. Jennison

Reading is a highly valued skill, with basic reading ability of ever-increasing importance for success in modern society. However, a significant number of young people are unable to learn to read to the expected level, despite normal levels of intelligence. Such children are commonly identified as dyslexic, with the term dyslexia literally meaning 'poor performance in reading'. The frequency of dyslexia is considerable. For example, Yule, Rutter, Berger and Thompson (1974) found that in their sample of over 5000 British children between the ages of 9 and 11, three to six percent could be classified as dyslexic. It has been observed that boys more frequently have reading problems than girls do (e.g. Benton, 1975; Lovell, Shapton & Warren, 1964).

A 'working definition' of dyslexia has been developed by a collection of specialists from related fields, including members of the Orton Dyslexia Society Research Committee, the National Center for Learning Disabilities, the National Institute of Child Health and Human Development, and scientists and clinicians from universities in the United States and Canada (Lyon, 1995). The definition is as follows:

> "Dyslexia is one of several distinct learning disabilities. It is a specific language-based disorder of constitutional origin characterized by difficulties in single word decoding, usually reflecting insufficient phonological processing. These difficulties in single word decoding are often unexpected in relation to age and other cognitive and academic abilities; they are not the result of generalised developmental disability or sensory impairment. Dyslexia is

> manifest by variable difficulty with different forms of language, often including, in addition to problems with reading, a conspicuous problem with acquiring proficiency in writing and spelling" (Lyon, 1995, p.9).

The working definition described above refers to what is commonly termed 'developmental dyslexia', where the child fails to learn to read normally. However, dyslexia may also be 'acquired', where the individual exhibited normal reading ability but, following a stroke or head injury, is no longer able to read to the same level. Much research has compared the two varieties of dyslexia and attempted to draw parallels between the displayed symptoms of developmental dyslexia with those of acquired dyslexia (including Castles & Coltheart, 1993; Coltheart, Masterson, Byng, Prior & Riddoch, 1983; Ellis, 1985; Frith, 1985; Masterson, 2000; Temple & Marshall, 1983). The following literature review will describe theories of reading development and models of adult reading. It then discusses how adult reading models have led to an approach which emphasises the identification of subtypes in both acquired and developmental dyslexia. We plan to discuss research and theory relating to subtyping and developmental dyslexia, and conclude with a description of general and specific treatment programmes for various types of developmental dyslexia.

Models of Reading

Developmental models of reading.

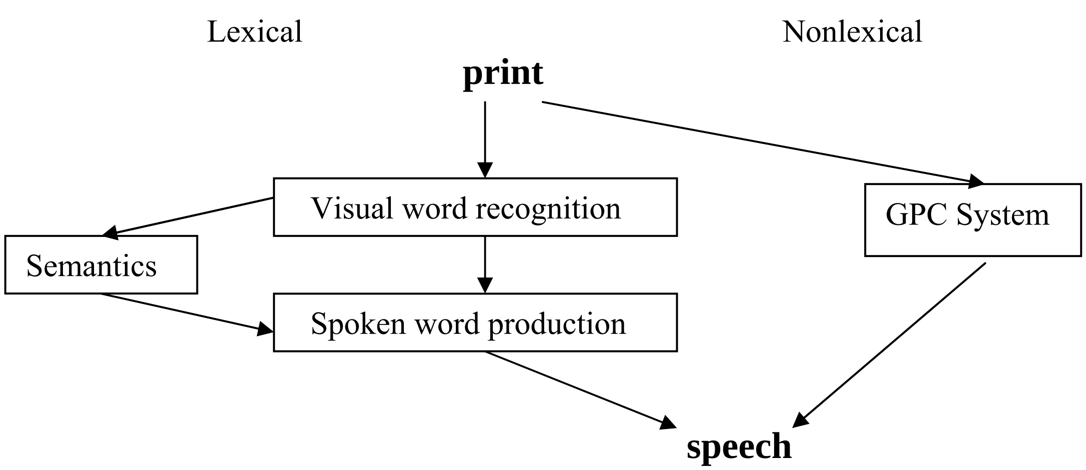
Two prominent stage theories of reading were developed in the 1980's to explain the processes that take place during normal reading development. In 1981, Marsh, Friedman, Welch and Desberg presented a cognitive-developmental theory of reading acquisition based around four stages. The first stage is Linguistic Guessing (Glance and Guess), where the child focusses on one aspect of the word, for example the first letter and, relying on context, guesses the word. When reading an unknown word, the child simply substitutes a syntactically and semantically appropriate word. Stage two is Discrimination Net Guessing, in which the child extends their focus to include other word features such as word length and the final letter. Such word features are only processed to the extent necessary to discriminate one printed word from another. As the child is now focussed on the co-ordination of two items of information – the context and some of the graphemic information – they are more likely to hesitate or refuse to respond when encountering a new word. Unless they have an appropriate word already stored in their visual memory, they realise they do not know the word. From Stage two onwards, the child builds up their sight vocabulary. The third stage is Sequential Decoding, where the child is able to decode basic grapheme-to-phoneme correspondences, having learnt that certain letter groups are generally pronounced in the same way. When presented with an unknown word, the characteristic response of children in the third reading stage is to decode the word, that is, 'sound out' the word. However, children at this stage view the alphabetic principle as invariant, with each letter corresponding to one sound only. In the final stage, Hierarchical Decoding, the child has achieved skilled reading, and is context-sensitive and able to perform some reading by analogy. By this stage children are able to deal with conditional rule patterns and other complex rules of orthographic structure.

Marsh et al.'s (1981) model was modified by Frith (1985), who created a three-stage model. The three phases of Frith's model are each characterised by a strategy. In the first phase, the child employs a logographic strategy, where familiar words are instantly recognised by identifying several key visual features. Words may be guessed on the basis of context, but children may often refuse to respond if they are not able to access an appropriate word from their sight vocabulary. The second phase is characterised by an alphabetic strategy, and the child develops an understanding of individual phonemes and graphemes and the relationship between them. In the final orthographic phase, the child is able to systematically recognise words as whole complex orthographic units, without requiring phonological conversion.

Adult models of reading.

In contrast to the developmental models of reading, models have also been developed to describe the processes involved in skilled reading in adults. A number of researchers have proposed that, in order to read aloud, skilled readers require two key skills; the ability to sound out words, so they are able to identify an unfamiliar word, and the ability to store and access visual lexical memories of words, so they are able to recall the sound and meaning of words, particularly irregular words (Coltheart, 1985; Marshall & Newcombe, 1973). If either of these abilities is not present, or has been impaired, the individual's overall reading ability will also be impaired. This idea led to the development of the dual-route model of reading, as presented in Figure 1 (Coltheart, 1978, 1985). This model, in its simplest form, identifies two procedures that are used when reading a word aloud – the lexical procedure, and the nonlexical procedure.

Figure 1. The basic dual-route model of reading (adapted from Coltheart, 1985)



When a word is presented, the lexical procedure operates as follows: the individual looks up the word in their 'mental dictionary', where each previously encountered word is stored as an orthographic input representation, enabling the whole-word unit to be recognised visually. The orthographic input representation is connected with a corresponding phonologically-specified entry, which enables the individual to then produce the word correctly. Each word unit is also connected with a semantic representation of the word, which can also be activated, so the individual recognises the meaning of the word as well. Justification for the existence of the lexical procedure comes from the observation that irregularly spelled words (such as yacht) cannot be sounded-out. Correct reading of these words relies on the individual's ability to recall the lexical structure of the word and corresponding pronunciation. However, as the lexical procedure requires access to lexically stored orthographic representations, it cannot be employed to read never-before-seen nonwords (pronounceable letter-strings, for example bick, spatch, ganten), as these are not associated with specific orthographic representations.

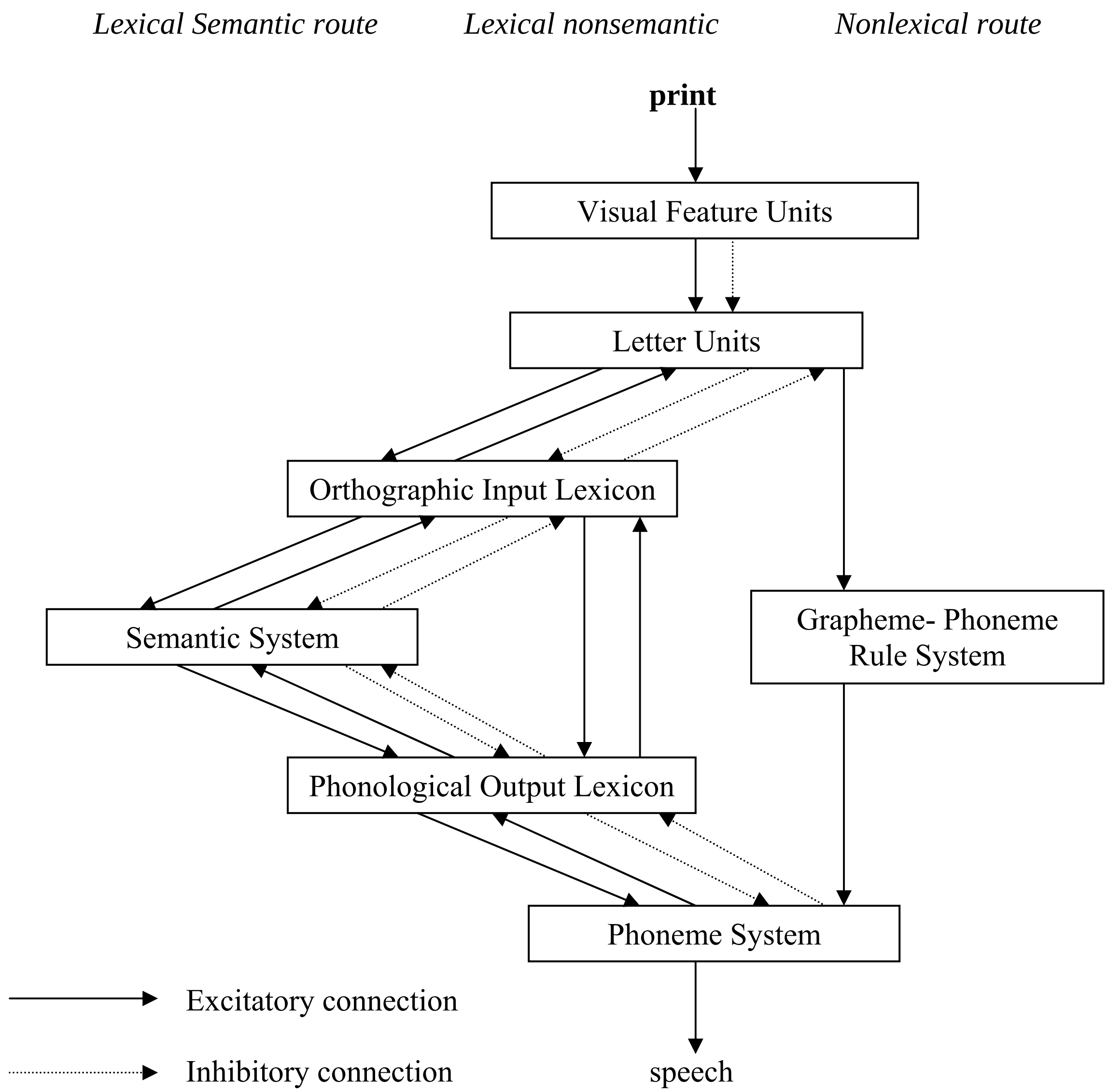
Rather than relying on the individual's 'mental dictionary' to recognise words orthographically, the nonlexical procedure converts spelling into sound by relying on the individual's knowledge of the rules relating graphemes (letters) to phonemes (sounds), termed grapheme-to-phoneme correspondences (GPCs). The operation of the nonlexical procedure operates using three components – graphemic parsing, phonemic assignment and blending. When presented with a word, the following sequence takes place: the individual initially breaks the word down into the individual graphemes, and then assigns each of these graphemes to its corresponding phoneme, in accordance with the GPCs. The separate phonemes are then blended together to create a cohesive pronounceable unit. As the nonlexical procedure operates by applying GPC rules, rather than relying on individual units for each specific word, it can be used to process regular words, including words not encountered before, and also nonwords. However, application of the nonlexical procedure to reading irregular or exception words would result in regularization errors, for example reading ‘island’ as “iz-land”.

According to the dual-route model, the reading aloud of nonwords can only be achieved by using the nonlexical procedure, whereas the correct reading aloud of irregular words is reliant on the use of the lexical procedure. The reading aloud of regular, real words can be achieved employing either the lexical or the nonlexical procedure, however the faster speed of the lexical route suggests that familiar regular words are read using this procedure. For an individual to be able to competently read aloud, both procedures must be fully functional and well developed. Specific difficulty with nonword reading, following a stroke or head injury, was first recognised as a distinct difficulty in 1979 by Derouesne and Beauvois and later termed acquired phonological dyslexia. This specific difficulty may be understood within the dual-route model as a selective deficit in the nonlexical reading procedure. In such individuals, real word reading is relatively well preserved (Temple & Marshall, 1983). The opposite impairment may occur to an individual following a stroke or head injury, and the characteristic deficit is in reading irregular words (Marshall & Newcombe, 1973). This is interpreted as due to impairment in the lexical reading route, and a consequent reliance on the intact nonlexical procedure to read words. As well as affecting the reading of irregular words, this reliance on the phonological procedure can result in impaired homophone comprehension. As the patient does not have direct access to the semantics of the word from its orthographic representation, they access the word's meaning via its sound, which creates difficulty for homophonic words. For example, given the definition ‘a fruit’, such an individual may have difficulty correctly selecting between the words ‘pear’ and ‘pair’, as they both result in the same pronunciation when GPC rules have been applied to sound the words out. Such difficulties were identified by Marshall and

Newcombe in 1973 as a subtype of acquired ‘visual dyslexia’. This was later termed acquired surface dyslexia.

A recent computational version of the dual-route theory has been developed; the Dual Route Cascaded Model (DRC) (Coltheart, Rastle, Perry, Langdon & Ziegler, 2001). This is illustrated in Figure 2. As in the classical dual-route model, there are both lexical and nonlexical procedures, or routes, for reading. The routes each comprise a series of components or levels, which are depicted in the model by the boxes. Within each of the levels are the individual representations or units, e.g. letters in the Letter Unit step, words in the Orthographic Input Lexicon step. The units within the different levels influence one another in two ways; inhibition, where the activation of one unit inhibits the activation of other units, and excitation, where the activation of one unit results in the activation of other units. In the Figure below, inhibitory connections are depicted as dotted arrows, and excitatory connections with solid arrows.

Figure 2. The dual-route cascaded model of visual word recognition and reading aloud (Coltheart et al. 2001)



The DRC model operates in a cascading fashion, whereby as soon as there is any activation in one level, it flows on to others. As illustrated in Figure 2, adjacent levels in the DRC model generally communicate with others using both excitatory and inhibitory connections. However, there are three exceptions: 1) connections between the orthographic and phonological lexicons are excitatory only, 2) the communication between the visual features and the letters units is in one direction only, from features to letters, and 3) the grapheme-phoneme correspondence system only operates in one direction and purely in an excitatory manner.

According to the DRC model, reading operates via three routes: the Nonlexical route, and the two subroutes of the Lexical route - the Lexical Semantic route and the Lexical Nonsemantic route. Three of the model's components are common to all three routes: 1) the Visual Feature units, which identify the position where each letter is situated within the word, 2) the Letter units, which identify which specific letters are involved, and 3) at the output end, the Phoneme System, which generates a complete phonological representation of the word to be produced. As well as these common levels, each of the routes also involves route-specific levels. The nonlexical procedure (termed the GPC route in the DRC model) is reliant on the individual's knowledge of grapheme-to-phoneme correspondence (GPC) rules, and functions similarly to the Nonlexical route of the basic dual-route model described above: when presented with a word or nonword, the positions and features of the word's letters activate the corresponding Visual Feature and Letter units. The appropriate GPC rules are identified and applied, and then the corresponding phonemes are activated, resulting in pronunciation of the word. The Lexical route also operates similarly to the basic dual-route model, but has been subdivided in the DRC model into the Lexical Semantic route and the Lexical Nonsemantic route. The Lexical Nonsemantic route operates as follows: First, as with the GPC route, the positions and features of the word's letters activate the corresponding Visual Feature and Letter units. Then, the word's specific orthographic lexical unit is identified within the Orthographic Input Lexicon, activating the corresponding phonological lexical unit within the Phonological Output Lexicon. Finally the appropriate phonemes are activated and the word is read aloud. The Lexical Semantic Route follows the same levels as the Lexical

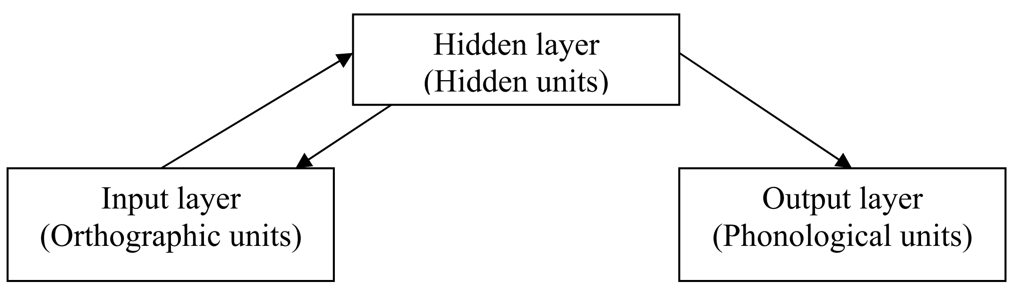
Nonsemantic route, but also activates the word's semantic representation within the Semantic System.

The DRC model advances the basic dual-route model of reading with its allowance for interaction between levels, that is, that information regarding each presented word is fed in both directions along the route, so the information attained from each level is combined and summated. Furthermore, both routes in the DRC model process each presented word simultaneously, enabling information from each route to be examined, with the most solid pronunciation then being presented. This simultaneous input from each route provides some account for the slower processing speed when reading irregular words compared to regular words – the inconsistent information provided by the two routes results in further analysis being required to determine the correct pronunciation of the irregular word, thereby taking a longer period of time. The division between the Lexical Semantic and Lexical Nonsemantic routes is able to account for the presence of non-semantic readers (Gerhand, 2001), who are able to read regular, irregular and nonwords aloud flawlessly, yet have severely impaired comprehension of the same written words.

As the DRC model is based on the dual-route model of reading, it provides a useful framework for describing acquired dyslexia. Acquired dyslexia can be simulated through lesions of the model or alteration of one or more parameters of the model. Coltheart et al. (2001) also discuss the value of the DRC model in the field of developmental dyslexia, as a means of characterising the current status of a dyslexic child and assisting in identifying the area with which they are struggling. We consider this issue in more detail later.

An alternative to the dual-route approach is Seidenberg and McClelland's (1989) parallel distributed processing (PDP) model of reading. This is illustrated in Figure 3. This model contains three levels: the input layer (orthographic units), the output layer (phonological units), and the hidden layer which mediates the connections between the input and output layers, via hidden units. Each of the units in these layers has an activation level and is connected to all the units in the next level by a weighted connection, which is either excitatory or inhibitory. These connections initially have random weights, resulting in random pronunciation of orthographic inputs. The network is then trained using backpropagation to progressively increase accuracy of pronunciation. The PDP model was proposed as a single-route model of reading, whereby the orthographic and phonological information interact together to result in oral reading. Lexical memory does not consist of entries for individual words, such as is contained in a lexicon, but rather comprises a certain pattern of activation across units, according to the correspondences learned from previously presented words. When a word or nonword is presented, a pattern of activation is encoded over the orthographic units, according to the letters and their relative positions within the word. The activations of hidden units are computed accordingly, then used to compute activations for the phonological units according to weighting, as well as providing feedback for new activations at the orthographic units. The activations of each of these units is then computed and combined to determine the word's pronunciation.

Figure 3. Seidenberg and McClelland's (1989) PDP model



As a result, words with higher frequencies are more easily produced because they will have been more frequently presented to the model during training, so will have had a stronger influence on the values of the weighted connections. Similarly, words that are more regular (in keeping with GPC rules) or consistent with other words of similar spellings (e.g. the word ‘kind’ is irregular, but its pronunciation corresponds with many of its orthographic neighbors such as ‘mind’, ‘grind’) are also more easily learned. This is also due to the letter combinations and corresponding pronunciations being more frequently presented and therefore greater weighting being learned between the specific orthographic and phonological units (Jared, McRae & Seidenberg, 1990).

This connectionist model received criticism for its poor non-word reading ability, which was found to be far below that of normal readers (Besner, Twilley, McCann & Seergobin, 1990). Also, in an analysis comparing the PDP model and the dual-route model for reading aloud, Coltheart, Curtis, Atkins and Haller (1993) noted that this PDP model is incapable of adequately accounting for a number of skills, including: 1) skilled reading aloud of nonwords, 2) surface dyslexia, 3) phonological dyslexia, and 4) developmental dyslexia.

To counter the limitations the PDP model had with pronouncing nonwords and performing lexical decision, Plaut, McClelland, Seidenberg and Patterson (1996) developed a revised version of this connectionist model. The revised model used more refined and realistic orthographic and phonological input and output representations, by excluding any sequences of letters that do not occur in the English language, for example ‘zx’. This revision resulted in the model having improved performance on nonword reading, at a similar level to skilled readers. Plaut et al.’s revised model also extended Seidenberg and McClelland’s PDP model by incorporating semantics as an additional layer, with connections to both the orthographic and phonological units. This inclusion enabled the model to better account for the two subtypes of dyslexia. According to Plaut et al.’s model, phonological dyslexia arises due to impairment of the connections between the phonological and orthographic levels, resulting in reliance on the interactions between the orthographic units and the semantic units for reading, that is, a reliance on recalling whole-word units. In comparison, surface dyslexia is accounted for by impairment of units at the semantic level, resulting in reliance on the connections between the orthographic and phonological units.

Although the revised PDP model (Plaut et al., 1996) addressed two of Coltheart et al.'s (1993) concerns (How do skilled readers read nonwords aloud? How does surface dyslexia arise?), it still fails to adequately account for the presence of phonological dyslexia, and developmental dyslexia. Coltheart et al. state that the PDP model proposes that individuals with phonological dyslexia rely on the semantics layer for reading. However, Coltheart et al. counter this proposal by citing research that indicates that some phonological dyslexics present with weaker semantic processing abilities than their reading ability (e.g. Funnell, 1983). This finding limits the PDP model's account of both acquired and developmental phonological dyslexia. Coltheart et al. state that the PDP model also fails to account for 'pure' cases of developmental surface dyslexia, where children exhibit poor irregular word reading, but normal or near-normal nonword reading.

In comparison, the dual-route model is able to clearly answer each of Coltheart et al.'s key questions regarding skilled reading aloud. The transparent separation of the two reading routes enables clear reference to be made to the development or impairment of one of the specific reading routes, and any dissociation between levels of functioning. As a result, the dual-route theory clearly accounts for the two dyslexia subtypes, enabling clear distinction to be made between them, as will be further discussed below.

Further revisions of both the dual-route and the connectionist models of reading continue, in an effort to continue to progress towards the development of a model that can closely represent skilled adult reading. Both models have been further developed to enable their application to the learning of disyllabic and polysyllabic words and nonwords, to increasingly acknowledge the complexity of the English language (Ans, Carbonnel & Valdois, 1998; Rastle & Coltheart, 2000).

Subtyping of Developmental Dyslexia

The concept of subtyping within developmental dyslexia - identifying subgroups characterised by different abilities and difficulties, similar to that within acquired dyslexia – originally stemmed from literature such as Boder's (1968, 1971) diagnostic patterns for dyslexia. Boder identified three subtypes of developmental dyslexia, according to the child's word reading and spelling abilities: 1) dysphonetic dyslexia, characterised by a primary deficit in grapheme-phoneme integration, resulting in the child being unable to sound out words (corresponding with phonological dyslexia), 2) dyseidetic dyslexia, characterised by a primary deficit in the ability to perceive letters or words as whole-word units, resulting in a reliance on sounding each word out (corresponding to surface dyslexia), and 3) mixed dysphonetic-dyseidetic dyslexia, characterised by primary deficits in both phonetic word-analysis skills and whole-word reading. Inspired by Coltheart's dual-route model of reading (1978, 1985), researchers in the field of cognitive neuropsychology went on to seek support for the model from cases of developmental dyslexia, where one reading route had developed at a markedly delayed rate, impairing the child's phonological or whole-word reading ability. Such cases were indeed found (initially by Coltheart et al., 1983; Temple & Marshall, 1983); some key examples will be described below.

The initial case study of developmental dyslexia that drew similarities with acquired phonological dyslexia was presented by Temple and Marshall (1983). They assessed HM, a 17-year-old girl of average intelligence, whose reading and spelling abilities were significantly impaired, over five years behind her age-norms. When reading nonwords, HM showed greater impairment than when reading words, including irregular words, and was completely unable to read any long nonsense words or long unusual regular words correctly. HM frequently made lexicalisation errors (replacing the nonword with an incorrect word response, which is visually similar to the nonword), e.g. when presented with the nonword 'fraze', HM read "freeze". This was interpreted within the dual-route model as an over-reliance on the intact lexical route. Following analysis of HM's data, Temple and Marshall concluded that all of the features of her reading abilities were consistent with the features characteristic of acquired phonological dyslexia. They concluded that HM could be confidently regarded as a developmental phonological dyslexic.

In the same year, the first published case study of a child with developmental dyslexia that expressed comparison with acquired surface dyslexia was presented (Coltheart et al., 1983). Coltheart et al. described two individuals whose reading performances were characterised by significantly greater difficulty reading irregular words than regular words, the key impairment associated with surface dyslexia. One of the individuals was an acquired dyslexic, while the other, CD, was a developmental dyslexic. When reading irregular words, both individuals tended to produce regularisation errors, where the words are sounded out in a phonological manner, e.g. reading the word 'steak' as "steek". This is again a standard characteristic of surface dyslexia. Analysis of spelling errors also indicated great similarity between the individuals, with the majority of errors again being phonologically based, e.g. 'search' was spelled "surch". Coltheart et al. concluded that surface dyslexia can occur both as acquired and developmental dyslexia.

Subsequent case reports further support the existence of the subtypes of developmental dyslexia. In the case of phonological dyslexia, there are now a large number of documented cases of a developmental form of this disorder (for example, Broom &

Doctor, 1995b; Campbell & Butterworth, 1985; Masterson, Hazan & Wijayatilake, 1995; Seymour, 1990; Snowling & Hulme, 1989; Snowling, Stackhouse & Rack, 1986; Temple, 1997). Indeed, recently cases of 'pure' developmental phonological dyslexia have been reported, where the individual displays severely impaired nonword reading, but is able to read real words with normal latencies and accuracy (Campbell & Butterworth, 1985; Funnell & Davison, 1989; Howard & Best, 1996; Hulme & Snowling, 1992; Stothard, Snowling & Hulme, 1996). Howard and Best (1996) analysed the reading performance of M-J, an 85-year-old woman identified to have developmental phonological dyslexia. They found that M-J displayed a pure case of phonological dyslexia, with significant impairment in reading nonwords but no impairment in reading real words, with no effects of regularity. As daily reading rarely requires the processing of nonwords, M-J had never felt any difficulty with 'real-life' reading. According to the dual-route model of reading (Coltheart, 1978), M-J's normal word reading ability can be explained as having developed solely from a whole-word lexical approach, whereby each word has been learnt as a whole word and stored in the visual word memory with its associated pronunciation.

As with developmental phonological dyslexia, further case studies have been presented to support the existence of a developmental form of surface dyslexia (for example, Broom & Doctor, 1995a; Castles & Coltheart, 1996; Goulandris & Snowling, 1991; Samuelsson, Bogges & Karlsson, 2000; Seymour, 1990; Temple, 1997). For example, a single case study conducted by Castles and Coltheart (1996) with MI, a 10-year-old boy with developmental surface dyslexia, found that although he was reading irregular words extremely poorly, he was performing at his age-appropriate level when reading regular words and nonwords. Castles and Coltheart concluded that, with his extreme difficulty in reading irregular words yet normal regular and nonword reading, MI seemed to represent a 'pure' case of developmental surface dyslexia. This is consistent with Castles and Coltheart's (1993) earlier group study that identified several other cases of developmental surface dyslexia.

To ensure the analysed cases of developmental phonological and surface dyslexia were not simply exception cases, and that the general subtypes were reliably applicable to developmental dyslexia, Castles and Coltheart (1993) examined the presence of these two syndromes in a group of developmental dyslexics. They assessed the lexical and sublexical reading skills of 56 children with developmental dyslexia, and 56 age-matched controls. Each child read through lists of regular words, irregular words and nonwords, and their performance was compared to that of control subjects. Three of the developmental dyslexia subjects attained extremely low scores for all three wordtypes and so were omitted from further analysis. A large proportion of the dyslexic subjects scored below the confidence limits for irregular word reading (40 out of 53), and for nonword reading (39 out of 53). Furthermore, ten of these subjects attained scores that fell below the lower confidence limits exclusively for irregular word reading, whilst scoring within the limits for nonword reading, thereby meeting the criteria for surface dyslexia. Eight subjects met the criteria for phonological dyslexia, with their nonword reading scores falling below the confidence limits but their irregular word reading scores falling within the limits. This was interpreted as indicating support for the subtyping procedure of developmental surface and phonological dyslexia, and for the dual-route model of reading, whereby one route (lexical or sublexical) develops whilst the other fails to develop.

Cognitive features associated with developmental phonological and developmental surface dyslexia.

A number of specific cognitive features have been identified as related to the two subtypes of developmental dyslexia. We'll consider the associated features of phonological dyslexia initially, followed by the associated features of surface dyslexia.

Phonological dyslexia has been correlated with one key cognitive ability – a basic phonological processing deficit. This deficit has been found to be present in a number of case studies and group studies of developmental phonological dyslexics (Broom & Doctor, 1995b; Campbell & Butterworth, 1985; Funnell & Davison, 1989; Hatcher, Hulme & Ellis, 1994; Howard & Best, 1996; Hulme & Snowling, 1992; Masterson, et al., 1995; Seymour, 1990; Snowling et al., 1986; Snowling & Hulme, 1989; Stothard et al., 1996; Temple, 1987, 1997; Temple & Marshall, 1983). Phonological processing ability can be assessed in a number of areas, including rhyme fluency and judgment, phoneme deletion, phoneme blending, and sound categorisation (Goulandris & Snowling, 1991; Hatcher & Hulme, 1999). Although there appears to be a relationship between poor phonological processing and developmental phonological dyslexia, there is debate regarding which is causal. It has been argued that phonological dyslexia results from impaired phonological awareness (Bradley & Bryant, 1983; Snowling, 1980), but also the opposite argument, that developmental phonological dyslexia is a cause of phonological processing deficits (Morais, Bertelson, Cary & Alegria, 1986; Morais, Cary, Alegria & Bertelson, 1979). Stuart and Coltheart (1988) adopt a middle ground on this argument, stating that phonological awareness and reading acquisition have a reciprocal interactive relationship.

Developmental surface dyslexia has been associated with slower reading response times than normal readers (Seymour, 1987a). The slowed reading has been observed not only in the reading of irregular words but also regular words, and results in an overall slower reading speed. In comparison with developmental phonological dyslexics, Seymour found that the developmental surface dyslexics exhibited slower reading times for regular and irregular words, which was further slowed as the word length increased. This supports the contention that developmental surface dyslexics are not able to read using a whole-word approach, so must rely on a phonological reading approach, whereby each grapheme must be serially processed, thereby slowing the process.

It has been suggested that poor visual processing abilities and visual memory deficits may be associated with surface dyslexia (Boder, 1971; Bayliss & Livesey, 1985). In a review of research focussed on the subtyping of reading disabilities, Watson and Willows (1993) found support for the presence of a subgroup of reading disabled individuals who have accompanying deficits in some aspect of visual perception, visual memory or visuo-spatial-motor skills. Due to the majority of the reviewed research not being cognitive neuropsychologically-based, Watson and Willows were not able to relate these difficulties to particular subtypes of developmental dyslexia. However, Goulandris and Snowling (1991) reported a case study of JAS, a 22-year-old developmental surface dyslexic who relied almost solely on phonological strategies for reading rather than whole-word techniques. Following extensive testing, Goulandris and Snowling uncovered a severe deficit in tasks requiring visual memory and visual analysis, in particular memory for geometric shapes. They concluded that visual memory might be essential for the development of the lexical reading route, which is necessary for reading irregular words.

Further evidence for visual deficits in developmental surface dyslexia was in a case study of EBON, a 15-year-old developmental surface dyslexic who had experienced a childhood occipital brain lesion (Samuelsson et al., 2000). After presenting EBON with a stem completion task requiring her to say the first word that came to mind after a word stem was presented, Samuelsson et al. found that EBON, although normal on general visuo-spatial skills, exhibited a significant impairment in her visual priming ability compared to age-matched controls. Whereas her results indicated her auditory implicit memory did not significantly differ from the controls, Samuelsson et al. suggested EBON had an overall deficit in her visual implicit memory. Samuelsson et al. concluded that the left occipital lobe (the site of EBON's lesion) is involved in visual implicit memory. Furthermore, the occipital region contributes to the acquisition of word orthography, suggesting a possible relationship between implicit memory and the acquisition of visual representations of whole words.

However, some research has not supported the correlation between developmental surface dyslexia and any visual difficulties. Cestnick and Coltheart (1999) investigated the connection between developmental dyslexia and performance on the Ternus test of visual motion detection. The performance of a group of dyslexic children and a group of children without reading difficulties was compared, and no correlation was found between Ternus test performance and irregular word reading scores. Similarly, Castles and Coltheart's (1996) case study of MI, a boy with developmental surface dyslexia, revealed that he performed well above average on tasks that assessed the skills of visual recognition, assessed using the Warrington Recognition Memory test, visual recall – the Benton Visual Retention test, and visual sequential memory – Visual Sequential Memory subtest of the Illinois Test of Psycholinguistic Abilities.

Although research has found a consistent correlation between phonological dyslexia and a deficit in phonological processing ability, research into the cognitive correlates of surface dyslexia has not been conclusive. Further research is required to investigate the possible relationship between visual difficulties and surface dyslexia.

Criticisms of the cognitive neuropsychological subtyping of developmental dyslexia and alternative views.

Despite the supporting evidence for the use of cognitive neuropsychological subtyping for characterising developmental dyslexia, a number of criticisms have been raised. These criticisms include questioning of the validity of the subtypes and their associated features, whether the specificity of the subtypes fails to address the variability found within reading disorders and whether dyslexia is a more heterogeneous disorder. These criticisms will be covered below.

Some research has not supported the concept of two distinct subtypes of developmental dyslexia. Wilding (1989) reviewed several case studies of developmental dyslexia – both phonological and surface (including Bryant & Impey, 1986; Campbell & Butterworth, 1985; Coltheart et al., 1983; Holmes, 1973; Seymour, 1986; Temple & Marshall, 1983). He reanalysed the data, and concluded that all the cases exhibited poor nonword reading, not just the individuals identified as phonological dyslexics. Similarly Manis, Seidenberg, Doi, McBride-Chang and Petersen (1996) conducted a study comparing the reading performances of 51 developmental dyslexics (both phonological and surface), 51 age-matched controls and 27 younger reading-age matched controls. They found that, of the dyslexic children who fitted the ‘surface dyslexia’ classification (that is, exhibited very poor orthographic reading skills), they also exhibited phonological deficits compared to the chronologically age-matched children. That is, as well as exhibiting poor reading of exception words, the developmental surface dyslexics were also poor at reading regular words and nonwords, so showed poor overall reading, not only in one specific area. This finding supported prior longitudinal research conducted by Manis, Custodio and Szeszulski (1993) who administered a battery of tests to a group of dyslexic children on two occasions over a two-year period. They found that, despite receiving ongoing reading training, the children failed to significantly 'catch-up' to their 'normal' chronologically-age matched peers, on any of the key phonological and orthographic processing skills required for reading. Manis et al (1993) concluded that all dyslexic children, both phonological and surface dyslexic have primary deficits in phonological processing and secondary deficits in orthographic processing, and do not exhibit specific difficulties in concordance with the dual-route model.

The subtype of developmental surface dyslexia has been further challenged as to whether its key characteristics are specific to surface dyslexia. Bryant and Impey (1986) conducted a comparison of reading age-matched controls and the two original cases of developmental dyslexia; developmental phonological dyslexia, HM (Temple & Marshall, 1983) and developmental surface dyslexia, CD (Coltheart et al. 1983). On a range of reading-related tests, such as homophone matching, and irregular word and nonword reading, Bryant and Impey found that the specific patterns claimed to be determinants of developmental surface dyslexia (including greater difficulty reading irregular words, and the production of regularisation and stress errors), were also common features of normal reading-age matched children. That is, non-dyslexic children who had the same reading age as the surface dyslexics made similar errors. This suggests that the characteristic difficulties claimed to be specific to surface dyslexia are normal for a certain reading level. Bryant and Impey concluded that the symptoms used to describe developmental surface dyslexia could not be used to identify a specific reading difficulty. This finding has been supported by other research. Manis et al. (1996) found that the performance of the developmental surface dyslexics they studied was similar to the reading-age matched children on both nonword and irregular word reading, whereas the developmental phonological dyslexics' performance on nonword reading fell below that of the reading-age matched children. They concluded that this similarity between surface dyslexics and younger reading-age matched children indicates that surface dyslexia is comparable to a developmental delay in reading.

It has also been argued that, similar to being attributed to developmental delay, developmental surface dyslexia may result from a child's lack of exposure to reading materials and a lack of experience reading and practicing reading skills (Stanovich, Siegel & Gottardo, 1997; Snowling, Hulme & Bryant, 1995, cited in Stanovich et al., 1997). This is supported by Castles, Datta, Gayan and Olson's (1999) research into the genetic and environmental influences on developmental dyslexia, which found that surface dyslexia is significantly influenced by environmental factors. Some researchers have suggested that socio-economic status may be a contributing factor: for example, Stanovich et al. (1997) suggested that the high incidence of surface dyslexics in their sample may be a result of their sample being drawn from schools with low levels of achievement and diverse populations, which resulted in the children experiencing a low level of exposure to print both at home and at school. To determine the accuracy of this concept a systematic study is required comparing reading ability across socio-economic groups.

Another key criticism that has been made against the cognitive neuropsychological subtyping approach to developmental dyslexia is that the two subtypes are too distinct and fail to acknowledge the variability within reading disorders. Following their comparison of developmental dyslexics and reading age-matched controls, Bryant and Impey (1986) noted that reliance on the traditional cognitive-neuropsychological subtyping of developmental dyslexia requires children with reading difficulties to be placed into one of two distinct categories; surface or phonological. They argue that this ignores the fact that reading difficulties are more appropriately described as fitting into a continuum between 'normal' and 'disabled'. This single continuum does not allow for the two dyslexia subtypes to exist;

it classifies children into a level of reading disability without identifying any specific areas of difficulty.

A further conceptualisation of reading ability as a continuum has been proposed by Murphy and Pollatsek (1994) who compared the performance of 65 dyslexics with 65 reading age-matched and 17 chronologically age-matched children. Following completion of five reading measures, a phonological segmentation task and four word retrieval tests, each child's results indicated that there were no discrete subgroups of developmental dyslexia within the dyslexic group, and that a similar range of variance was exhibited by both the dyslexics and the reading-age controls. It was concluded that reading ability lay on a continuum, with phonological skills in reading at one end and whole-word reading ability at the other (Figure 4). The majority of children are placed somewhere in the middle, however there are a few who exhibit dissociated reading behaviour. Murphy and Pollatsek state that these children should not be categorised into the discrete subgroups of phonological and surface dyslexia however, and placement on the continuum is more appropriate.

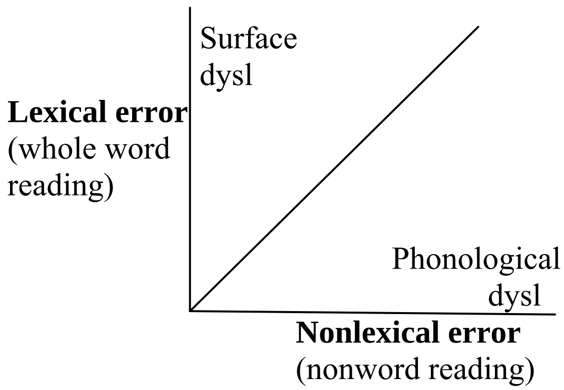
Figure 4. Reading ability continuum (based on Murphy & Pollatsek, 1994)

High phonological skills/ Low whole-word skills ————————	Average phonl/ average whole-wd reading ———————	High whole word reading /low phonl

However, this continuum does not directly contradict the presence of the subtypes of dyslexia as determined by the dual-route theory of reading. Rather, it suggests that although the two extreme reading abilities as described by the subtypes do exist, the vast majority of individuals with reading difficulties fit between them. This concept is supported by Brunsdon, Hannan, Nickels and Coltheart (2002a) who, employing a cognitive neuropsychological framework, discuss the presence of the two distinct subtypes of dyslexia; phonological and surface, and, in addition, the presence of a larger subgroup of individuals with 'mixed' dyslexia. Mixed dyslexia is generally characterised by a particularly severe functional reading impairment, incorporating the characteristics of both phonological and surface dyslexia. Brunsdon et al. developed and employed a cognitive neuropsychology-based treatment programme for an individual with mixed dyslexia, which was effective in improving the individual's reading ability.

Similarly, Seymour (1987b; Seymour & Bunce, 1994) discusses the heterogeneity of dyslexia, suggesting that reading abilities (and disabilities) are best presented as a two-dimensional scatter-plot with lexical abilities (whole-word reading) on one axis and nonlexical (nonword reading) on the other (Figure 5). Whole-word and nonword reading tests would assess the child's ability with error rates plotted on the graph. The diagonal line represents equivalent error rates in both whole-word and nonword reading, which can be used to approximate a 'normal' reader's responses. Those individuals whose scores fall above the line exhibit a greater number of errors reading irregular words, whilst those whose scores fall below the line have greater difficulty reading nonwords. Those scores far from the line indicate more 'pure' cases of developmental dyslexia (that fit within the classification of phonological and surface dyslexia; see Figure 5), however, by employing the scatterplot model for identifying reading ability, a greater range and degree of reading abilities would also be able to be identified.

Figure 5. Reading ability scatterplot (based on Seymour, 1987b).



Bryant and Goswami (1987) suggested that rather than two distinct subtypes of developmental dyslexia, there are a greater variety of reading difficulties. In a review of relevant research they investigated the process of learning to read and learning the associated skills. They concluded that both normal readers and disabled readers exhibit differences in the ways they learn to read compared to the standardised models of reading, and rather than there only being two methods of reading – phonological and whole-word, Bryant and Goswami state that there are other strategies such as the use of analogies. This belief would have potential to impact upon training programmes and methods employed to assist children having difficulty learning to read. Bryant and Goswami's theory does not support the dual route theory in there being two clear subtypes of dyslexia, instead it posits the idea that reading difficulties can take many forms due to children learning to read using different strategies and there being the potential for difficulties to arise within any of the strategies.

Reading Treatment Programmes

There have been many remedial reading programmes developed to assist children with developmental dyslexia, or reading difficulties in general. Reading programmes have adopted two major approaches to remediation: a) phonological instruction, and/or b) whole-word exercises, each of which will be described below (Chard & Osborne, 1999). In phonological instruction, children are taught how to analyse words into their segments to identify correspondences between letters and sounds and/or to sound out words directly. This is particularly valuable when presented with an unfamiliar word. In contrast, whole word instruction focusses on identifying each word as a whole unit, rather than a sequence of letters or sounds. Whole-word training increases the child's sight vocabulary and is particularly valuable for accurate reading of exception or irregular words. The most frequently adopted method for whole-word reading is the use of flashcards, presenting each word individually.

Phonological treatment programmes.

Phonological treatment programmes are frequently based around improving the child's phoneme awareness: children are taught to break down words into their segments (phoneme segmentation) and learn to combine sounds together to make longer words (phoneme blending). Other programmes focus on the written word: they teach children to recognise the correspondence between graphemes and phonemes and to sound out words directly. Specific phonological training programmes based on these techniques will now be discussed.

Wallach and Wallach (1976) conducted one of the first documented studies investigating the influence of grapheme-to-phoneme correspondence (GPC) awareness training on reading ability. Their field study involved adults from the community working with children who scored low on a general reading test. The children received daily one-on-one training over a period of approximately one year, teaching them three skills that Wallach and Wallach had identified as prerequisite for basic reading skills; learning to recognise letters and their associated sounds, learning to sound out simple words, and reading simple stories. At the completion of the training programme the experimental group scored significantly higher than matched controls on word recognition, sentence reading and phoneme awareness tests.

Another instructional programme, aimed at improving the reading skills of learning disabled students aged between seven and twelve years was developed by Williams (1980, 1981). The programme, called *The ABDs of Reading,* provided explicit training in three reading-related skills – 1) phoneme analysis (*A*), where children learned to analyse syllables and short words into phonemes (same as phoneme segmentation), 2) phoneme blending (*B*), and 3) decoding (*D*), where children learned GPCs to enable them to decode words. The initial pool of 146 children was sourced from specific classrooms developed for children who had been identified by the local school authorities as 'learning disabled'. After completing a pre-test assessing each child's word analysis and decoding skills, 63 children deemed likely to profit from the programme were selected. These children completed basic training in word syllabification initially, then completed daily, 30-minute, small group sessions over six months, focussed on training four skills; 1) phoneme analysis, 2) phoneme blending, 3) GPCs, and 4) decoding. Following the programme, the pre-tests were re-administered with the majority of posttest scores significantly higher than those of a control, no-treatment group. Following the programme, instructed children were able to decode untrained nonwords, indicating generalised improvement in their phonemic decoding skills.

In comparison to the two programmes previously mentioned, which focussed on developing the children's phonemic awareness and GPC awareness through standard exercises involving phoneme analysis and blending, other reading programmes have employed additional techniques. The Auditory Discrimination in Depth programme (ADD; Lindamood & Lindamood, 1975) focussed solely on improving phoneme awareness, through development of the child's awareness of articulatory feedback. In the ADD programme students are taught that the 24 consonant sounds in English can be categorised according to their place and manner of articulation, e.g. 'p' and 'b' are labelled as 'Lip Poppers', 't' and 'd' as 'Tip Tappers', with pictures indicating the form the mouth takes when producing these sounds. Vowels are identified as long or short, and the manner of articulation, e.g. long 'e' sound is paired with a smile mouth shape, short 'o' is paired with an open mouth shape. Studies have found that kindergarten and first grade classes who received the ADD programme showed greater ease acquiring both beginning reading skills and continued reading skills, than classes who received standard reading curriculum (Lindamood, 1985; Howard, 1986, both cited in Lindamood, Bell and Lindamood, 1997). The ADD programme has also been found to be effective when used with older reading-disabled children in improving their phonological and phonemic awareness, and applying this awareness to word decoding (Alexander, Anderson, Heilman, Voeller & Torgesen, 1991; Truch, 1994).

A long-term phonological training programme developed by Bradley and Bryant (1985) focussed on teaching children sound categorisation skills. Children in the experimental group were trained to group pictures together according to the names having sounds in common, for example, grouping together 'cat' and 'cup' as they both have the same first sound. Two experimental groups received two years of training; one group received training solely in sound categorisation through the grouping of picture cards into groups where the name of the pictures had one or more sounds in common, (Sound Categorisation Only), whereas the other experimental group were taught sound categorisation skills for the first year, but in the second year were also taught how to express these sound categories by spelling them with plastic letters (Sound Categorisation + Letters). In comparison, children in the control group were trained to group the pictures according to conceptual categories, for example, objects found indoors versus objects found outdoors (Conceptual Categorisation). Bradley and Bryant also included another control group (No-Training) who received no training at all. 65 six-year old children who displayed poor sound categorisation skills were divided into the four groups, matched across groups, and were each seen for one individual session each week for a total of forty sessions. Following the training period, the two experimental groups (Sound Categorisation Only and Sound Categorisation + Letters) achieved between three- to seventeen-months higher reading and spelling ages than the control groups, and the between-group difference was significant. There was also a consistent difference between the two experimental groups, with the Sound Categorisation + Letters group scoring higher than the Sound Categorisation Only group on reading and spelling tests, with the spelling test scores significantly higher. There was no difference in the mathematics abilities between the experimental groups and the control groups, indicating that the training in phonological awareness clearly assisted reading and spelling ability specifically.

There are a diverse number of reading training programmes classified under the ‘phonological’ category, and although most appear to be effective, there has been little comparative research conducted to investigate how they rate related to each other. With the aim of identifying programmes that achieve generalisation, Lovett, Borden, DeLuca, Lacerenza, Benson and Brackston (1994) compared two forms of word identification training. One programme trained phonological analysis and blending and provided direct instruction of letter-sound correspondences (phonological programme), while the other programme trained the acquisition, use and monitoring of word identification strategies (strategy programme). The four word identification strategies were; 1) word identification by analogy, 2) seeking the part of the word they know, 3) attempting variable vowel pronunciation, and 4) 'peeling off' prefixes and suffixes in multisyllabic words. Both training programmes resulted in clear generalisation of skills and transfer of learning indicated in improved reading of untrained regular words. The phonological programme resulted in greater generalised gains in phonological awareness, and the strategy programme resulted in broader-based transfer for real words, both regular and exception words.

Torgesen, Wagner and Rashotte (1997) also conducted a comparative study investigating the effectiveness of two phonological training programmes following a long-term intervention; a) phonological awareness plus synthetic phonics (PASP) training based on the ADD programme (Lindamood & Lindamood, 1975) and b) embedded phonics (EP) training. The EP training involved four key activities – acquiring sight words using word drills and games, instruction in letter-sound correspondences, writing the words, reading sentences containing the words. Kindergarten children with weak phonological skills were identified and randomly assigned to one of these training conditions or to one of two control groups; c) a regular classroom support (RCS) condition, and d) a no-treatment control (NTC). The two training programmes differed in their time allocated to specific reading activities, with the PASP programme focussing the majority of its time on phonological training, while the EP programme focussed primarily on reading text. Each child received four 20-minute one-on-one sessions each week for two and a half years. At completion results indicated that children who received intervention (in either the PASP or the EP programmes) showed an overall improvement in reading comprehension (Torgesen, Wagner, Rashotte, Rose, Lindamood, Conway & Garvan, 1999). Children in the PASP programme were found to have significantly stronger skills in phonological awareness, phonemic decoding and context-free word reading than the children in the EP programme.

In a comparison of phonological awareness training (PAT) and word analogy training (WAT), O'Shaughnessy and Swanson (2000) trained 45 reading disabled children in small groups for 30 minutes a day, three times a week for six weeks. A control group received maths training for this same period of time. The PAT programme was designed to enhance children's awareness of the sound structure of words with four sets of activities; rhyming, sound blending, sound segmenting and reading and spelling activities. The WAT programme trains children in identifying unknown words by use of analogy, for example, a child who already knows the words 'flag' and 'let' can use them to help decode the new word 'magnet'. Results indicated that children in both reading programmes achieved significant gains in learning phonological awareness and word identification skills, in comparison to the control group. However, children in the PAT group made significantly greater gains in phonological awareness than the WAT-trained children. Children from both training groups were able to apply their newly learnt skills to uninstructed material, indicating good generalisation. O'Shaughnessy and Swanson concluded that the findings suggest that there are different paths to reading remediation, which can be effectively applied to small groups within the public school setting.

Another comparative study was conducted recently by Joseph (2000), comparing the effectiveness of two contemporary techniques for training phonics; word box instruction, which involves children identifying the individual phonemes within a word and dividing them into 'boxes', and word sort instruction, where words are sorted into categories based on common phonemes or on common spelling patterns. 42 second-grade children were divided into three matched groups; word box, word sort or control, and the experimental groups received 50 individual 20-minute lessons over a twelve-week period. The word box trained group and the word sort trained group both performed significantly better than the control group on phonemic segmentation and word identification tests. The word box group was also superior at phoneme blending and pseudoword naming compared to the control group, and the word sort group was superior on spelling performance compared to the control group.

The phonological treatment programmes indicate that training in phonemic and GPC awareness are highly effective in improving the child's ability in performing the specifically trained skills; primarily segmentation, blending and 'sounding-out' words. However, there is little research supporting the concept that improvements in such areas results in improved overall reading ability. Further research is needed to determine the relationship between phonemic and GPC awareness, and reading ability to further evaluate the worth of such training.

Whole-word treatment programmes.

Relatively few documented studies have been conducted using whole-word or lexical treatments. Nevertheless one reading remediation programme available in New Zealand, which focusses on the whole-word approach, is Reading Recovery (Clay, 1985). The programme focusses on providing one-on-one intervention for reading-delayed 6-year-old children, training them primarily by reading books with them that involve both hard and easy text. Activities involving letter identification and story writing are also included. Children receive 30 to 40 minutes of individual reading instruction per day by a specially trained Reading Recovery teacher, with the aim of the child achieving a level of reading equal or above their class average. The process usually takes between 12 and 20 weeks.

The programme places great emphasis on teaching word recognition skills in context, with Clay (1985) commenting:

> "The learning of details such as the sounds of letters or a list of words is completed through text reading and text writing and (his) interaction with (his) teacher" (p.52).

Clay (1985) has reported that Reading Recovery is an effective programme in improving reading, however the use of a control group who were not matched in pre-assessment reading skills to the treatment group makes the comparison of these groups difficult. Further research into the effectiveness of Reading Recovery, conducted by Iversen and Tunmer (1993), compared three matched groups of first-graders who received either the standard Reading Recovery programme, a Reading Recovery programme modified to include training in phonological awareness, or a control group who received the standard school intervention programme. Results indicated that, although the mean improvement for children in both Reading Recovery groups was significantly higher than the mean improvement for children in the control group, the children in the modified Reading Recovery group reached the higher levels more quickly than the standard group. Iversen and Tunmer concluded that the efficiency of Reading Recovery can be improved with the addition of phonological awareness training, thereby creating a combination of both whole-word and phonological training.

Another whole-word training programme to expand children's sight word recognition was conducted by Lalli and Shapiro (1990). The programme trained the skill of self-monitoring and then incorporated self-monitoring and an external contingent reward process to the training programme. Each child read a list of words every session and after reading each word they then heard the experimenter read the word on the tape, thereby providing them with the correct pronunciation, and feedback regarding their accuracy. After an average of approximately 40 five-minute sessions, each child's sight-word vocabulary increased as a result of training, with both self-monitoring alone, and self-monitoring plus external contingent rewards.

Although whole-word training is widely accepted as an integral part of learning to read, very few related studies have been documented. Currently there is little research supporting the effectiveness of whole-word training, however the small number of studies suggest that whole-word training is helpful, although may be more effective when presented in combination with phonological training (as suggested by Iversen & Tunmer, 1993).

Comparison of whole-word and phonological approaches to treatment.

Research has been conducted to compare the effectiveness of whole-word and phonological training programmes for reading, and to ascertain which training type is more effective. Such research has the potential to play a highly valuable role in assisting schools and educational institutions to determine the most efficient means for teaching children to read, both in general, and for reading-delayed children.

One of the first documented comparative studies was conducted by Olson, Foltz and Wise (1986) and involved the employment of a computer-based reading system with speech feedback. Feedback could be requested by the child when they were unsure of a word, and was provided in three different levels; one whole-word approach, and two phonological approaches - feedback segmented by syllables, and feedback where each syllable was segmented into two parts. The participants were second to sixth graders who were below the 10^{th} percentile locally in word decoding skills. Olson et al. found that, following reading six short stories aloud off the computer and requesting feedback, the subjects in all of the treatment conditions were able to correctly read a significant proportion of their initially misread words. However, there was no significant difference between the different feedback conditions. Olson and colleagues then extended the training programme by expanding the talking-computer system, monitoring the child's comprehension of the stories, and running the programme for an average of four half-hour sessions per week, for an average of 7 weeks (Olson & Wise, 1992). Trained subjects improved four times more in phonological decoding skills than control subjects, and trained subjects also improved twice as much as control subjects in word recognition. However, again no significant advantage was found for any specific feedback types; whole-word, or the two types of phonological - syllabic or onset-rime feedback.

In a comparison of the effectiveness of a whole-word training programme, a phonological training programme and a control study skills programme, Lovett, Warren-Chaplin, Ransby and Borden (1990) worked with 54 reading disabled children for 35 60-minute sessions each. In the whole-word training, both regular and exception words were taught using flash cards, with the teacher telling the child the word and then the child practising reading the word each time the card is presented. In the phonological training, exception words were taught using the same methods as the whole-word programme, but regular words were taught focussing on the sounding-out of phonemes and learning common GPCs. Although there were slight differences in skill-improvements between the programmes, the whole-word and the phonological training programmes were equally effective overall in improving word recognition on the instructed words. However, neither group showed any posttest advantage on uninstructed reading vocabulary, indicating no generalisation from the training programmes to reading untreated words.

Another study compared the effectiveness of training in phonological strategies and/or whole-word reading training. Conducted by Hatcher et al. (1994), reading-disabled seven-year olds received one of three training programmes; Phonological Training Alone, Reading Training Alone, and Phonological and Reading Training Combined. The Phonological Training Alone programme involved no reading training, focussing solely on the sounds within words and how these can be moved and manipulated to create new words. The Phonological and Reading Training programme combined reading training activities modelled on Reading Recovery and its whole-word approach (Clay, 1985) but included the addition of phonological activities from the Phonological Training Alone programme. The Reading Training Alone programme consisted entirely of the whole-word reading training activities. Following completion of the programmes, results indicated that although the Phonology Alone group showed the most improvement on phonological tasks, and the Reading Alone group did show some gain in reading ability, the significantly greatest progress in reading was attained by the Phonological and Reading Training Combined group. Further analysis of the results (Hatcher & Hulme, 1999) found that the children's phoneme manipulation skills were a strong predictor of their responsiveness to remedial reading, with stronger phoneme manipulation skills resulting in the individual being more likely to improve their reading ability as a result of remediation.

A comparison of two short-term (10 sessions of approximately 12 minutes each) programmes was conducted by O'Connor and Padeliadu (2000). They trained 12 first-grade remedial readers to read regularly spelled 3-letter words using either a sound-blending programme (phonologically-based) or a whole-word reading programme. The sound-blending programme involved the children being taught to blend the first two letter sounds of the word and then to add the final consonant e.g. 'cap' – "/c/-/aaaa/, /caaa/ - /p/, cap". In comparison the whole-word approach focussed on the instructor reading 3-letter-words from flash cards with the child repeating the words. Following training, both groups had made significant progress on reading the instructed material. No significant differences were found between the two treatment programmes; however delayed posttests identified the phonological blending treatment was more effective for retention of the reading skills and did result in generalisation of the skills to uninstructed words.

Connelly, Johnston and Thompson (2001) investigated whether 6-year-old beginning readers would differ in reading ability and comprehension when taught to read by either a phonics approach or a "book experience" non-phonics approach, where the children primarily learnt to read through reading grade-level books either independently, in small groups guided by a teacher, or with the whole class, with the teacher reading from a large book as the children watched. Two schools in Scotland were observed where reading was taught in an intensive phonics programme, and two matched schools in New Zealand were observed where reading was taught in a "book experience" programme. Rather than focussing exclusively on reading delayed children, this study involved a general sample of children, with a range of reading abilities. Children received the classroom-reading programme for approximately one hour per day over a four-month period. Although the two groups made equal gains in word recognition, the phonics-taught children had higher reading comprehension, made more attempts at reading unknown words, and made more contextually appropriate errors. The non-phonics-taught children were much faster at reading familiar words but were poorer at phoneme segmentation and nonword reading tasks. The better reading comprehension of the phonics taught children might be a result of their more frequent attempts at reading unknown words and greater reliance on contextual information to assist this.

Research investigating the effectiveness of whole-word and phonological reading programmes is yet to make definitive conclusions regarding which programme, if either, is consistently more effective. As discussed above, the current research comparing the training programmes has found that both programmes generally result in equivalent gains in word recognition, with some research finding generalisation of the trained skills to be more effective with phonological training programmes rather than whole-word. All of the training programmes cited above were effective in training the targetted reading-related skills. Findings of research studies that have included both phonological and whole-word training techniques in a single training programme (Hatcher et al., 1994, Iversen & Tunmer, 1993) indicate that the combination is more effective than either phonological or whole-word training techniques individually. Further research is now required to identify whether either set of skills (phonological or whole-word) is more strongly correlated with reading ability, to direct the focus and composition of future reading programmes.

Tailored treatment programmes - developmental phonological dyslexia.

Although some of these reading remediation programmes/strategies have been highly successful, given the heterogeneity of developmental dyslexia (as suggested by cognitive neuropsychological research) it would be surprising if one of the strategies were effective with all children experiencing reading difficulties. An approach that has emerged within the cognitive neuropsychology literature to address this has been the development of some remediation programmes targetting the characteristic difficulties of the subtypes of developmental dyslexia; phonological and surface, and tailored to meet an individual's needs. These cognitive neuropsychology treatment studies have three key factors: 1) they use a single case study approach, 2) they include an extensive pre-treatment analysis of the person's impairments in comparison to normal abilities; and 3) they use treatment designs that control for extraneous effects, such as practice effects or spontaneous recovery (see Coltheart, Bates & Castles, 1994, for a general discussion of this approach).

A phonological treatment programme based on the dual-route model of reading was developed by Seymour and Bunce (1994) for DK, an eight-year old boy with developmental phonological dyslexia and dysgraphia. The treatment focussed on training word and nonword reading and spelling, through the teaching of grapheme-to-phoneme correspondences (GPCs). Each word or nonword was broken up into three components; the initial consonant (IC), the vowel (V) and the terminal consonant (TC). Each component was colour-coded onto coloured cards and employed for anagram activities and for reassembling to create different words. These activities assisted DK in identifying consistency and patterns between graphemes and phonemes. DK received weekly one-hour training sessions over a period of approximately 15 months. The treatment programmes resulted in significant improvement in DK's reading and spelling of untrained nonwords, indicating generalisation of skills. A strategic change in his reading was also observed, whereby DK slowed down his reading to enable him to sound out unfamiliar words correctly.

In a case study by Broom and Doctor (1995b), an eleven-year old developmental phonological dyslexic, SP, was treated using an individually tailored programme. SP had a high IQ but his reading and spelling ages were over one year behind his chronological age. He was particularly poor at reading low-frequency words and nonwords, indicating developmental phonological dyslexia. The remediation programme focussed on extending SP's knowledge and use of GPCs in reading. Following the initial period of pretesting, SP completed a reading test of regular low-frequency words to determine which of the 20 most common GPCs he found the most difficult. The 12 most challenging GPCs were identified and each therapy session focussed on introducing a new GPC, by teaching SP a set of regular words all featuring the target GPC. Broom and Doctor employed a modified version of Bradley's teaching method (detailed in Bryant & Bradley, 1985), which makes use of lower-case plastic letters to aid word visualisation. For each word, SP was asked to read the words and identify commonalities in the spelling and sounds of the words. SP used the plastic letters to spell the words then wrote the words into an exercise book saying the name of each letter as he wrote it, sounding out the word and reading the word. This procedure was repeated at home after the lesson and again before attending the following lesson. At the end of each lesson SP combined the words into a mnemonic sentence to remind him of the way to pronounce the target GPC. Items from the previous lesson were revised at the beginning of each new lesson. Remediation was conducted individually for three 25-minute sessions each week over a period of six weeks, interspersed with training and comprehension tests. Results found a significant improvement in SP's reading of both familiar and unfamiliar words and nonwords containing trained GPCs, indicating that SP advanced his phonological awareness skills. There was also a significant improvement of SP's reading of words and nonwords containing untrained GPCs. However, this improvement was significantly less than the improvement in reading words containing trained GPCs, thereby indicating a specific therapy effect to the treated GPCs. There was no significant change in SP's performance on the control tasks that assessed reading comprehension, auditory comprehension, and mathematics. This indicates that the remediation programme was specifically effective in assisting SP in advancing his phonological reading skills.

Cognitive neuropsychological research has indicated that treatment programmes developed to remediate acquired phonological dyslexia can also be effectively implemented with developmental phonological dyslexics. Brunsdon, Hannah, Nickels and Coltheart (2002a) executed a treatment programme with a young boy, DT, with mixed dyslexia; rather than exclusively having difficulty with either the nonlexical route for reading (phonological dyslexia) or the lexical route (surface dyslexia), he experienced multiple severe difficulties within the reading system. The treatment programme was based on previous remediation programmes designed for acquired phonological dyslexia (Berndt &

Mitchum, 1994; De Partz, 1986; Nickels, 1992), and focussed on improving phonological skills, through training that included GPC awareness and phoneme blending. Following four-and-a-half months of treatment, DT's nonword reading improved significantly, and a significant improvement in his general reading ability was also observed. The treatment programme improvements generalised to untrained nonword reading and regular word reading. Brunsdon et al. concluded that the study provided evidence for the effectiveness of cognitive neuropsychological rehabilitation models of reading in treating the severe, and largely unstudied, group of children with 'mixed' dyslexia.

Research investigating treatment programmes for individuals with developmental phonological dyslexia has focussed on training the poorly developed reading route – the nonlexical route, through directly training GPCs. The results have consistently found that the programmes are effective in improving the child's ability to sound out words containing the targetted GPCs, as well as finding some generalisation to other untrained GPCs. In the research cited above, an improvement in overall reading ability has not been found following completion of the phonological training programmes.

Tailored treatment programmes – developmental surface dyslexia.

There have been fewer remediation programmes specifically developed for developmental surface dyslexics. As the treatment programmes developed for acquired surface dyslexia and acquired surface dysgraphia (impaired spelling of irregular words) have focussed on training the skills that are also required for developmental surface dyslexia (irregular word and homophone reading), these programmes will be examined first. Two of the few published remediation programmes for developmental surface dyslexics will then be presented.

One of the first treatments for acquired surface dyslexia was a short-term programme developed by Behrmann (1987) to retrain the reading and writing of homophone pairs by a 53-year-old woman, CCM. Over six weeks, eight new homophone pairs were trained at each of the weekly sessions. In training, each member of a homophone pair was written on a card, accompanied by a card with a picture of the item. The two cards were presented successively and compared and contrasted, with the different meanings discussed. The written words were then shuffled and CCM was required to: a) rematch them with their correct picture; then b) write the homophone words under the correct picture; then finally c) write each word to dictation in an exercise book. CCM also completed homework practice between sessions, involving forced-choice word-picture matching, sentence completion tasks and writing the correct homophone to a matched picture. Testing at two weeks post-therapy indicated a significant improvement in discriminating between the test homophones, as well as increased spelling accuracy on a set of untrained irregular words, indicating some generalisation. Behrmann's therapy technique was successfully replicated by Weekes and Coltheart (1996) to assist NW, an acquired surface dyslexic and dysgraphic in improving his spelling of irregular words. Again, spelling of the treated words improved significantly more than the untreated words, indicating a specific treatment effect. However, Weekes and Coltheart found no generalisation at all to untreated items.

Scott and Byng (1989) also retrained an acquired surface dyslexic, JB, in recognition and comprehension of homophones. Rather than relying on flashcards, they created a computer programme to train 68 homophone pairs using cloze tasks. JB was required to select the missing word of a sentence from six presented choices, including both words of the homophone pair, words that were visually related to the homophone pair, and pseudohomophones. After JB selected a word she would receive computer feedback as to whether her selection was correct or incorrect. If incorrect, she would be required to make further selections until the correct response was selected, then proceed to another cloze task until all 136 sentences (1 target sentence for each of the homophone pairs) had been completed. After each training session, a printout was provided stating JB's overall performance and rate of performance. The entire programme was completed by JB 29 times over a period of approximately 10 weeks. Over this period JB's performance steadily increased, almost to ceiling, whilst her time taken to complete the cloze tasks steadily decreased. Following post-tests, JB showed significant improvement in recognition and comprehension of both the trained and untrained homophones, indicating the effectiveness of the training, and some generalisation. However, unlike Behrmann's (1987) remediation, there was no generalisation in spelling of untreated irregular words.

In the same year, Byng published a further remediation study for acquired surface dyslexia (Coltheart & Byng, 1989). With patient EE, three therapy studies were conducted to improve his irregular word reading. The study was carefully designed to ensure any improvements were the result of therapy, and not due to spontaneous recovery, practice effects or nonspecific treatment effects. The first therapy study focussed on reading words containing the letter sequence 'GH', such as 'plough', 'cough' and 'ought'. Prior to therapy, EE read 5 of the 24 targetted 'GH' words correctly. Remediation involved the training of these 24 words using mnemonic aids, where each word was paired with a picture representing the meaning of the word, such as the word 'bough' being accompanied by a picture of a tree. Each card was explained to the patient and he spent 15 minutes each day at home, reading aloud the words with the help of the pictures. Half of the 24 words were trained for a period of 2 weeks and the other half left untrained, then for the following 2 weeks the second half of the words were trained and the first half no longer trained. The treated words improved significantly over the training period up to 100% correct, however the untreated words also significantly improved over the first training period, but not to the level of the treated words. The final perfect performance was still maintained one year later.

Coltheart and Byng's (1989) second therapy programme for EE trained 54 target words, which, instead of being paired with a picture, each had a mnemonic symbol drawn on the word, to prompt EE to focus on the overall wordshape whilst also assisting in comprehension. For each mnemonic symbol, EE helped to choose the pictures so they would be meaningful to him, e.g. for the word 'work' an envelope was drawn against the 'k' as EE's work was as a postman. As with the first therapy programme, EE carried out training at home, spending 15 minutes each day for seven days, reading aloud the words, with the help of the mnemonic pictures. EE's reading of the trained words improved, with reading of untrained words also improving, but to a lesser extent. Similar results were obtained from the final treatment programme where EE was trained on a further 101 words using the mnemonic technique. Coltheart and Byng concluded that it is possible to use a whole-word technique to train the reading of an acquired surface dyslexic, and that the mnemonic technique was effective for trained words, whilst also providing some generalisable improvement to untreated words. The programme design ensured the generalisation effect was not due to spontaneous recovery, but rather, a result of the therapy's effectiveness in improving the overall functioning of the visual lexicon. Weekes and Coltheart (1996) also employed a replication of this method to train their patient, NW, an acquired surface dyslexic and dysgraphic, in irregular word reading. After 7 days of practising reading 40 target irregular words with the aid of mnemonic picture cards, NW read the treated words significantly better than matched untreated words. He was also found to have improved his reading of those untreated words that he had previously known the meanings of. This improvement remained stable across the testing period of 4 months.

De Partz, Seron and van der Linden (1992) extended the mnemonic approach in their treatment programme for a French acquired surface dysgraphic and dyslexic patient, LP. To assist LP in relearning the reading and spelling of ambiguous and irregular words, De Partz et al. employed a visual imagery strategy, where each target word was written on a card and a relevant drawing was associated with the misspelt part of the word, e.g. for the word ‘flamme’ (French for ‘flame’) the two ‘m’s were drawn as fire flames over an open fire. LP initially learned to write 5 new words, presented with embedded drawings, each session for three months. Sessions were conducted three times a week. After the three months LP showed a significant improvement in the trained words, from 0% correct pre-training, up to 91% correct. There was also some improvement in untrained words although this was significantly lower than for the trained words (from 0% pre-programme up to 30%). In comparison, a matched list of words that were trained with the classic verbal didactic teaching (dictation of spelling), showed no significant improvement. De Partz et al. also found that LP was able to create his own embedded drawings, indicating the programme may be of long-term functional use.

Rather than employing the more time-consuming treatment involving visual mnemonics, Ellis, Ralph, Morris and Hunter (2000) employed a repeated presentation technique to train irregular word reading to BS, an acquired surface dyslexic. This technique was employed as BS’s problems in reading irregular words aloud mainly affected irregular words of low frequency and/or were abstract in their meaning, for example words such as ‘trough’ (low frequency) and ‘unique’ (abstract), so Ellis et al. felt BS would learn to reassociate the words and correct pronunciation through repeated exposure. Over two weeks BS was presented with differently ordered listings of the irregular training words, matched with audio readings of the lists. He read each of the lists, practicing any words that he had read incorrectly. At the completion of training, BS showed a significant improvement in reading the trained irregular words, however this improvement did not generalise to untreated items. Improvement was maintained over a three-month period.

Developmental surface dyslexics have had few remediation programmes specifically developed for them. Two case study examples have been conducted by Broom and Doctor (1995a) and Seymour and Bunce (1994). A clear example of a lexical treatment programme was conducted by Broom and Doctor (1995a), who investigated DF, an 11-year-old boy with poor irregular word reading and slow overall reading rates. The treatment programme focussed on developing DF's reading of irregular words, by extending his visual lexical memory. A list of 144 low-frequency irregular words was administered to DF on three separate occasions prior to any specific training, and there was no overall improvement in DF's reading of the words over this period, indicating the absence of any effects of spontaneous recovery or treatment effects. All words that had been failed more than once over the three administrations were selected for training. The resulting 66 words were divided into two frequency-matched sets. For the first training period (12 training sessions) one of the lists was trained, and, following testing of the trained list, 12 training sessions for the second list were conducted. The training method was adapted from Bradley and Bryant's (1985) 'Simultaneous Oral Spelling' programme: three or four words were introduced each lesson, then were defined and written by DF who said each letter as he wrote it. DF copied the word several times, and then wrote it from memory, saying each letter aloud. When DF could correctly write and spell the word, he wrote a sentence illustrating the word's meaning into his book. Each new word was also written on an index card. These cards were used as homework and presented as flash cards at the following lesson (Broom & Doctor, 1995a, p. 88). The words from the previous lesson were revised at the beginning of each lesson, and any words not known were retrained and included in that lesson's 'new' words. Broom and Doctor found a significant training effect, which was maintained over time. Additional untreated irregular words were assessed pre- and post-therapy, and there was no significant change in performance on the untreated words, indicating no generalisation.

In comparison, Seymour and Bunce (1994) trained RC, a nine-year-old boy with surface dyslexia by taking a compensatory approach, whereby RC's intact reading route – his nonlexical route, was trained and further strengthened. The programme focussed on training RC to read and spell the targetted regular and irregular words and nonwords by training his understanding of GPCs and word segmentation skills. Each component of the word (initial consonant, vowel and terminal consonant) was colour-coded onto cards and employed for anagram activities and for reassembling components to create different words using the same components, thereby assisting in the recognition of the consistency and patterns between GPCs. Although RC's reading and spelling improved throughout the programme, separate data is not provided for regular and irregular words, making it unclear whether RC made any improvement in reading irregular words, or whether improvements were solely based on regular words. There was no observable change in his approach to reading and spelling, with RC retaining his focus on sounding out words, as would be expected from the training. It is important to recognise the compensatory approach that this training programme adopted, with its primary focus being on further developing RC's phonological processing skills. The programme indicates that although a phonological-based programme may assist in further improving a surface dyslexic's reading of regular and nonwords, it does not change their reading approach, and does not appear to improve their reading of their challenging material, that is, irregular words.

A lexical treatment study conducted with a developmental 'mixed' dyslexic (Brunsdon, Hannan, Coltheart & Nickels, 2002b) found that the child, TJ, did show generalisation in reading untreated words. TJ exhibited extremely impaired reading across both the lexical and nonlexical routes and received training in reading two lists of regular words - one list was taught in conjunction with mnemonic cues (similar to Coltheart & Byng, 1989), while the other was taught using flashcards alone. Brunsdon et al. found that TJ significantly improved his reading on both sets of words with no significant difference in his performance between them, indicating that the use of visual mnemonic flashcards did not actually increase the effectiveness of their training programme. Brunsdon et al. conducted a second treatment study with TJ, focussing on more basic, high-frequency words, but this time solely relied on flashcards. At the completion of the study, TJ again exhibited significant improvement in reading the treated words, which generalised to an improvement in his reading of untreated words, his spelling and to some aspects of nonlexical processing, such as grapheme parsing and nonword repetition. This improvement in phonological skills is particularly noteworthy as the programme focussed on treating the lexical route for reading. The improvement may have resulted from the treatment programme focussing on teaching regular words, which differs to other lexical treatment programmes, which have focussed on irregular words that specifically require the lexical route to be read correctly. Brunsdon et al. (2002b) comment that, within the treatment programme, TJ noticed common patterns of grapheme-to-phoneme correspondence between words, e.g. he noted the similarity between the words ‘should’, ‘would’ and ‘could’. This indicates that, through the training of regular words, TJ was developing his nonlexical ability, which may account for the observed generalisation.

As can be seen in the previous discussion, it has been difficult to develop training programmes for surface dyslexia that are consistently effective in improving the individual’s ‘whole-word’ reading skills, as indicated by generalisation to untrained irregular words. Weekes and Coltheart (1996) suggested that the generalisation observed in remediation programmes for acquired surface dyslexia and dysgraphia may only occur for words which were premorbidly available, that is, words that were present within the visual memory prior to the injury. This generalisation may be a treatment effect whereby the individual's access and use of their orthographic input lexicon has improved as a result of treatment enabling them to better access premorbidly available words. Applying a similar treatment programme to developmental surface dyslexics, who have never been able to read the treated words, it would be expected that they would not show any generalisation effects (as indicated in Broom & Doctor, 1995a).

As discussed above, there have been very few research studies that have investigated treatment programmes that have been created specifically for developmental surface dyslexia. Those programmes that have been developed have commonly adopted techniques that were developed for acquired surface dyslexia. The training programmes have been effective in training specific words, however have not tended to result in any generalisation to reading untrained words, particularly untrained irregular words.

Aims of the Current Study

Currently, the research focus for developmental dyslexia in general, has largely been on group studies; identifying a group of individuals with reading difficulties, assessing for any general characteristics, training them for a specific reading skill (generally phonologically-focussed, rather than whole-word), and then re-assessing the group to investigate the impact of the skill improvement. Performance of the training group has often been compared with another group of individuals, generally a control group or a group who received an alternative training programme, usually another phonological programme. However, given the recent evidence supporting the existence of variability within the dyslexia population, any treatment outcome could be confounded by the nature of the participants tested. Indeed, the potential of techniques that are effective for small subsets of the dyslexia population (e.g. those with features of surface dyslexia) may never be revealed. Hence, it has been argued in the field of cognitive neuropsychology that individual case-studies are essential to aid in the development of theory and treatment methods for developmental dyslexia (Caramazza & McCloskey, 1988; Seymour, 1990; Broom & Doctor, 1995b). We can see from the review above that there have been few individual case-studies of developmental dyslexia where specifically tailored treatment programmes have been developed and implemented. However, by the same token, studies that focus on just one treatment for one individual leave us wondering whether any observed improvement would have been equally effective had another treatment been employed. Previous case study research has implied that phonological training programmes are more effective for developmental phonological dyslexics and whole-word training programmes more effective for developmental surface dyslexics, however no research has been conducted to investigate this. This is because most previous work has focussed entirely on a single, tailored treatment programme, and no studies have compared individual children's responses to two different training programmes.

The current research will adopt the cognitive neuropsychological framework, with the dual-route model for reading. We will address the issues outlined above, employing a 2-by-2 design comparing the relationship between dyslexia subtype (developmental phonological and surface) and programme type (phonological and whole-word). Both group and individual data will be presented, to enable comparison to be made between the overall responses of the phonological dyslexics and the surface dyslexics, and to analyse each child's individual responsiveness to each training programme.

The current research will select individuals with developmental phonological and developmental surface dyslexia from a group of reading delayed children, using the criteria set out by Castles and Coltheart (1993). That is, each of the children will exhibit a clear dissociation between irregular word and nonword reading abilities, with one at normal level, whilst the other is grossly defective. General reading ability and performance on related cognitive tests, including IQ, phonological processing and visual tasks will be examined and the effectiveness of two remediation programmes will be compared and contrasted for both subtypes – 1) A phonological remediation programme tailored to phonological dyslexics, partially replicating Broom and Doctor (1995b), and 2) a whole-word remediation programme, tailored to surface dyslexics. The Whole-word programme combines a range of training techniques. Some of the techniques are replicated, such as visual mnemonic flashcards (Coltheart and Byng, 1989) and cloze tasks (Scott and Byng, 1989). Other whole-word techniques were newly developed for the current study, in particular, the degraded images technique, which presented a degraded image of the word, which gradually became clearer over time. This technique focuses on encouraging the children to focus on the overall word, rather than relying on each individual letter. Effectiveness of each training programme will be measured by the child's reading of the targetted words before and after completion of training, as well as any generalisation shown in improved reading of untrained words. The scores for each subtype will be compared to assess for any influence of dyslexia subtype on training programme effectiveness. The goals of the current study are:

1) To explore the performance of developmental phonological and surface dyslexics on a range of cognitive tasks. Previous research and theory suggests that the phonological dyslexics are more likely to attain the weakest scores on tasks that involve phonological analysis such as phoneme deletion and phoneme blending. Developmental surface dyslexics on the other hand have been found to have difficulties on tasks involving visual analysis, including visual memory (Goulandris & Snowling, 1991) and visual memory (Samuelsson et al., 2000).

2) To assess the effectiveness of reading programmes specifically targetting the cognitive neuropsychological subtypes of developmental dyslexia; phonological and surface.
3) To compare and contrast the two types of treatment programmes for each individual, particularly noting the presence of any generalisation to untreated words.
4) To develop and evaluate techniques focussed on the development of whole-word reading skills, specifically to assess the effectiveness of the degraded images technique.

Chapter 2: Experiment 1

The underlying theoretical framework for the current research is the cognitive neuropsychological framework for reading: the dual-route model. This theoretical framework was employed as it has developed a clear computational paradigm for reading (the DRC model, as discussed earlier), which has successfully accounted for the key features exhibited by individuals with acquired and developmental dyslexia. The basic dual-route model comprises two routes, both of which are viewed as essential for skilled reading: 1) the Lexical route, reliant on visual whole-word recognition for reading, and 2) the Nonlexical route, reliant on the application of letter-to-sound correspondences to sound out words. Under the cognitive neuropsychological framework, developmental surface dyslexia is attributed to defective development of the Lexical route, and developmental phonological dyslexia is attributed to defective development of the Nonlexical route.

Experiment 1 comprises three sections. In the first section, Screening and Selection, a large group of reading-delayed children were assessed to determine the nature of their reading difficulties. This was accomplished through three steps: 1) the examination of each child's reading age, 2) a brief IQ assessment to determine the level of their reading difficulty, and whether it was inconsistent with their general IQ (as would be expected for dyslexia), and 3) a normed reading assessment of regular, irregular and nonwords (Coltheart & Leahy, 1996) to enable the researcher to identify any children who clearly fitted within the specifications of the cognitive neuropsychology subtypes of developmental dyslexia: phonological (associated with a specific weakness using the Nonlexical route, resulting in difficulties with nonword reading) and surface (associated with a specific weakness using the Lexical route, resulting in poor irregular word reading). The ten children who met the criteria were selected to continue with the research and receive remediation programmes.

In the second section, Background Testing, cognitive assessments were administered to each of the ten selected children, to fully assess the reading and reading-related abilities of the selected individuals. Initially, each child completed a full IQ assessment, followed by visual, visual-verbal and verbal tests, conducted to determine whether there were any differences between the skills of the phonological dyslexics and the surface dyslexics that may be correlated with their differences in their approaches to reading. The Visual tests comprised a range of tests, administered in an attempt to assess forms of visual memory (including memory for familiar items, geometric figures, and sequences) and visual discrimination (ability to discriminate between similar-looking pictures and separate overlapping figures and letters). These tests aimed to identify whether visual processing and visual memory deficits were more commonly found in individuals with surface dyslexia than phonological dyslexia, as suggested in previous literature (Bayliss & Livesey, 1985; Boder, 1971; Goulandris & Snowling, 1991; Samuelsson et al., 2000). The Visual-verbal and Verbal tests were selected to assess phonological skills, including sound deletion within words and repetition of nonwords. These tests aimed to identify whether phonological difficulties were more commonly found in individuals with phonological dyslexia than surface dyslexia (as has been commonly stated – see above), or whether phonological difficulties are present in both subtypes (Wilding, 1989; Manis et al., 1993; Manis et al., 1996). Throughout both the Pre-testing and Training programmes sections of Experiment 1, results are presented for the ten participants initially, and then results from two selected individuals (MT, a phonological dyslexic, and PS, a surface dyslexic) are examined in greater depth. These two individuals have been selected for further analysis as they clearly conform to the key requirements of the two dyslexia subtypes. To further emphasise MT's and PS's results, they are presented in italics throughout the tables.

The third section, the Training Programmes, involved each participant completing two training programmes. These training programmes used Broom and Doctor's (1995a, 1995b) case studies of treatment for phonological and surface dyslexics as a starting point in their development, as these case studies indicated effective cognitive neuropsychological intervention for developmental dyslexia, according to subtype. The two reading training programmes were as follows:

1) Phonological Training Programme. This focussed on improving the Nonlexical route, through training children's awareness of grapheme-to-phoneme correspondences (GPCs) and applying them to a range of regular words and nonwords. This training programme was a replication of Broom and Doctor's (1995b) successful case study intervention. The GPC awareness approach to phonological training is more implicit than some programmes, as, instead of rote-teaching letters and their corresponding sounds, this programme focusses the participant on 'families' of words containing the same GPCs, for example, the GPC 'oa' is contained within words including 'bloat', 'toad', 'moan', 'toast'. This approach was viewed as preferable as it encourages the child to generate their own awareness of GPCs based on exposure to examples, without the need for explicit learning of rules.
2) Whole-word Training Programme. This incorporated a range of techniques, including visual mnemonics, cloze tasks and degraded images, which emphasized the direct relationship between the word and either: 1) the word shape, and/or 2) the word meaning. Visual mnemonic flashcards involve the presentation of the printed word on a flashcard with a related illustration drawn around the word (see Appendix

L). These were employed in the Whole-word Training Programme as they have been found to be effective for improving irregular word reading in a number of intervention programmes for both acquired and developmental surface dyslexia (including Broom & Doctor, 1995a; Brunsdon et al., 2002b; Coltheart & Byng, 1989; DePartz et al., 1992; Weekes & Coltheart, 1996). They draw connections between the word, its overall shape and its meaning. Cloze tasks were administered as they also emphasise the meaning of the word, while requiring the participant to correctly select the word from a group containing both homophones and paralexias. This task aims to reinforce the direct association between the visual representation of a word and its meaning. The final technique, Degraded Images, was developed for the current research, and was designed to encourage the participant to focus on the overall shape of the word. By presenting the word in a degraded form, the participants were not able to rely on transcoding the individual graphemes in order to identify the word, but rather, had to look at the general shape of the word, which became clearer over time.

Adopting a two-by-two design, both training programmes were administered to each participant, to enable the training programmes to be compared and contrasted, according to the response of the dyslexia subtypes. Each participant's pre- and post-training programme results were analysed and compared across dyslexia subtypes. Generalisation to untrained words was also assessed for each programme, using three wordlists: regular words, which can be read using the Lexical or the Nonlexical routes; irregular words, which must be processed via the Lexical route in order to be read correctly; and nonwords, which require the Nonlexical route to be pronounced correctly. It was hypothesised that the phonological dyslexics would display greater improvements on both trained and untrained words following the Phonological Training Programme than the Whole-word Training Programme, and vice versa for the surface dyslexics.

Experiment 1, and the following Experiment 2, were approved by the Human Research Ethics Committee of the School of Psychology at Victoria University of Wellington.

Screening and Selection of Participants

Method

Participants.

Twenty primary and intermediate schools in Lower Hutt (ranging from Decile 1 to Decile 10) were approached regarding participating in the study. Seven of the schools declined to participate. Twelve of the schools published a notice in the school's newsletter, inviting parents to contact the researcher if their child was having difficulty reading and they were interested in the possibility of some reading training. The remaining school volunteered to participate actively in recruitment: (School A - a Decile 2 intermediate school i.e. among the 20% of schools with the highest proportion of students from low socio-economic backgrounds). At this school, classroom teachers identified children in their class who were at least one year behind their chronological age in reading, were at the age-appropriate maths level, and were not English as a second language students (Appendix A). All parents were informed via newsletter, and were invited to contact the school if they did not want their child involved or if they would particularly like their child tested (Appendix B).

The resultant sample comprised 45 children: 29 boys and 16 girls. The children ranged in age from 7 years 8 months to 13 years 7 months (mean age = 12 years 1 month). Six of the children were recruited through notices in school newsletters. The remaining 39 children attended School A.

The children were from a range of ethnicities; 22 were New Zealand European, 12 Pacific Nations, 9 Māori, 1 Asian and 1 Fijian-Indian. All of the New Zealand European and Māori children spoke English at home, however 10 of the Pacific children spoke their national language as well or instead of English at home (including Niuean, Cook Island

Māori, Samoan, Tongan). The Asian and Fijian-Indian students also spoke their native languages at home with the family.

Materials.

The initial test battery comprised the following tests: The Burt Word Reading Test – New Zealand Revision (Gilmore, Croft & Reid, 1981), the Neale Analysis of Reading Ability – 3rd Edition – Form 1 (Neale, 1999), Coltheart & Leahy's (1996) frequency-matched lists of regular, irregular and nonwords and the Block Design subtest of the Wechsler Intelligence Scale for Children – 3rd Edition (WISC-III; Wechsler, 1992). The Burt Word Reading Test is an individually administered measure of a child's word recognition skills. It has been standardised for New Zealand children and age norms are provided for New Zealand children aged from 6.0 years to 12.11 years. The Neale Analysis of Reading Ability enables assessment of an individual's reading of text in three areas – accuracy, comprehension and rate. Standardised scores (performance descriptors) are also available to determine the child's level – Very Low (VL), Below Average (BA), Average (A), Above Average (AA) and Very High (VH). The Third Edition of the Neale Analysis was standardised for a range of countries, including Australia (McKay & Barnard, 1999). The third edition comprises two parallel forms.

Coltheart and Leahy's (1996) wordlists comprise 30 regular words, 30 irregular words and 30 nonwords (see Appendix C). The sets of words are matched on the variables of frequency, imageability, word length and grammatical class. Age-related norms are available for each word set based on data obtained from 420 non-reading-disabled children aged 7 to 12. The normative data provides information regarding the ranges of scores that could be considered below normal or borderline; Band A is the range of scores into which no sample child fell – all children of the target age scored above this level in the normative sampling. Performance within this Band can be considered a definite indicator of a reading deficit. Band B covers the range of scores that are two standard deviations below the mean for each age group. These can be considered as indicating borderline of normal performance. Further reliability and validity information for some of the tests is presented in Appendix D.

Procedure.

Students from School A were tested individually in the school meeting room, during school time. The remaining students were tested at their homes after school.

Each child initially completed the Neale Analysis of Reading Ability, then read Coltheart and Leahy's (1996) wordlists. The Neale Analysis was administered according to standard procedure; the Coltheart and Leahy wordlists were presented on an Apple Macintosh laptop computer using the PsyScope programme (Cohen, MacWhinney, Flatt & Provost, 1993). The computer was placed so that the centre of the screen was eye-level. Each of the 90 words was presented individually and in random order, using lower case, Comic Sans 48-point font and situated in the center of the screen. Each word remained on the screen until the child had read it aloud, then the child pushed a key to advance to the next word. Following the Coltheart and Leahy wordlists, the WISC-III Block Design subtest, then the Burt Word Reading Test were administered according to standard procedures.

Following completion of the above tests, children who met the following three criteria were selected to participate in the Training Programmes: a) their reading age (as indicated by the Neale Analysis Accuracy age and the Burt Word Reading Test) was at least eighteen months below their chronological age, b) their scaled score on the WISC-III Block Design subtest was 8 or above, and c) their score on Coltheart and Leahy's (1996) wordlists indicated placement within different Bands for irregular word and nonword reading (either Band A for one and Band B or Normal for the other, or Band B for one and Normal for the other).

Results

Following the pretesting of 45 children aged between 7 years 8 months and 13 years 7 months (mean=12 years 1 month), raw and scaled scores for each child were calculated for each of the four tests given. Means and standard deviations of the scores for the 45 children are presented in Table 1.

Table 1 – see end

The children's scores indicate a wide range of ability, with scores on all tests ranging from very low up to normal or above normal. Results from the Burt Word Reading Test indicated that the mean reading age was more than two years below the mean chronological age. As discussed earlier, the scores attained on the Coltheart and Leahy wordlists are scaled, according to age norms, into three levels: 1= Band A, indicating a clear reading deficit, 2= Band B, indicating borderline performance, and 3= Normal. These scores indicate overall poorer scores in reading the nonwords and regular words, compared to the irregular words. It is of note that some children were reading at age-appropriate levels.

From the 45 children who participated in the general pretesting, ten children met the above requirements and were selected to continue in the training programmes. General information about each child is presented in Table 2. The group comprised seven boys and three girls, aged between 9 years 3 months and 12 years 4 months (mean age = 11 years 8 months). Six of the children were New Zealand European, two Samoan, one Māori and one Fijian-Indian. The Samoan and Fijian-Indian children spoke both English and their native language at home, however they had all been raised in New Zealand. Their scaled scores on the WISC-III Block Design subtest ranged from 8 (MJ) up to 16 (PS). Three of the children qualified as being in a lower band for irregular word reading than for nonword reading (MJ, ST, PS). These children will be referred to as ‘surface dyslexics’. A further seven children qualified as having weaker nonword than irregular word reading; these will be referred to as ‘phonological dyslexics’ (WC, MT, KI, GM, PJ, TT, LJ). Prior to conducting the programme pretests, each of the ten children and their parents completed consent forms (Appendices E and F).

Table 2 – see end

Discussion

The general pretesting resulted in a range of scores for all tests. Scores from the Coltheart and Leahy wordlists were relatively high, with the mean scores not indicating a predominance of Band A scores. However, this may also be a result of averaging across the subtypes of developmental dyslexia, such that poor nonword reading scores for developmental phonological dyslexics are counteracted by good scores attained by the surface dyslexics in reading nonwords, and vice versa for reading irregular words. The majority of the children tested were male (64%), which is consistent with the research that has indicated that the majority of children with developmental dyslexia are male (including Lovell et al., 1964; Benton, 1975).

Background Testing for Selected Participants

Method

Participants.

The ten individuals identified above completed the Background Testing.

Materials.

The first pretest administered to each child was the complete Wechsler Intelligence Scale for Children (Third Edition). The remaining pretests can be grouped as 1) visual, and 2) visual-verbal and verbal tests. Further validity and reliability information for some of the tests is presented in Appendix D.

1) Visual Tests. The visual tests assessed the child's visual memory and visual discrimination. Visual memory tests were the Benton Visual Retention Test (Fifth Edition; BVRT; Sivan, 1992), the Kaufman Spatial Memory and Gestalt Closure subtests (Kaufman & Kaufman, 1983), the Bead Memory subtest of the Stanford-Binet (Fourth Edition; Thorndike, Hagen & Sattler, 1986) and the Visual Number Span and Auditory Number Span subtests of the Kit of Factor-Referenced Cognitive Tests (Ekstrom, French, Harman & Dermen, 1976). Visual discrimination tests that were administered were the Identical Pictures subtest of the Kit of Factor-referenced Cognitive Tests (Ekstrom et al., 1976) and the Minimal Feature View Task and the Overlapping Figures subtests of the Birmingham Object Recognition Battery (BORB; Riddoch & Humphreys, 1993).

The Benton Visual Retention Test (BVRT) requires the participant to reproduce 10 geometric designs from memory, after viewing each design for a specified time period. The current research employed Administration A of the Form C designs, in which each design is viewed for 10 seconds, then covered and the participant must reproduce it. Two scores are obtained; one is a measure of the examinee's overall level of performance, based on the number of correct reproductions and is called the 'Number Correct Score'. It can range from 0 (minimum) to 10 (maximum). The other, the 'Number Error Score', provides information regarding the frequency of specific types of errors made by the examinee.

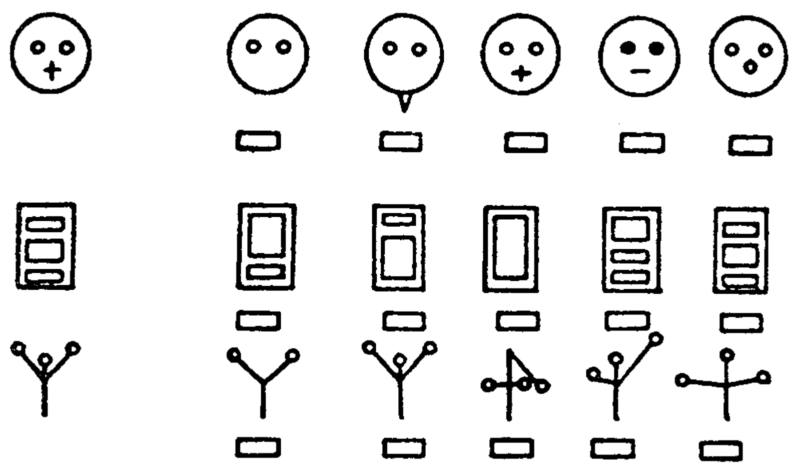
The Kaufman Spatial Memory subtest requires children to view 21 increasingly intricate pictures for a period of time, then recall the position of objects within the picture. Children indicate their response by pointing within a blank box matched in size to the original picture. The Gestalt Closure subtest requires children to correctly name 25 minimised and degraded pictures of objects (e.g. ship, elephant, typewriter).

In the Stanford-Binet Bead Memory subtest, children are presented with a picture of a certain sequence of beads, which is then removed and the child is required to create an identical pattern using their own rod and a box of assorted beads. Performance is expressed in terms of Standard Age Scores (SAS), which are normalised standard scores with a mean of 50 and a standard deviation of 8 within each age group.

The Visual Number Span subtest from the Kit of Factor-Referenced Cognitive Tests was administered to children using number cards (A6 size) with black printed numbers. A series of cards were presented to the child, one at a time, for two seconds each card, until the series was complete, then the child was requested to write down the numbers in the correct order. The series' ranged from 4 to 12 numbers. The first ten items of the subtest were administered. The Auditory Number Span subtest from the Kit of Factor-Referenced Cognitive Tests was also administered, to enable comparison between each child's auditory memory and their visual memory, as assessed by the Visual Number Span subtest. A series of numbers were read to the child, one at a time, until the series was complete, then the child was requested to write down the numbers in the correct order. The series' ranged from 4 to 11 numbers. Again, the first ten items of the subtest were administered.

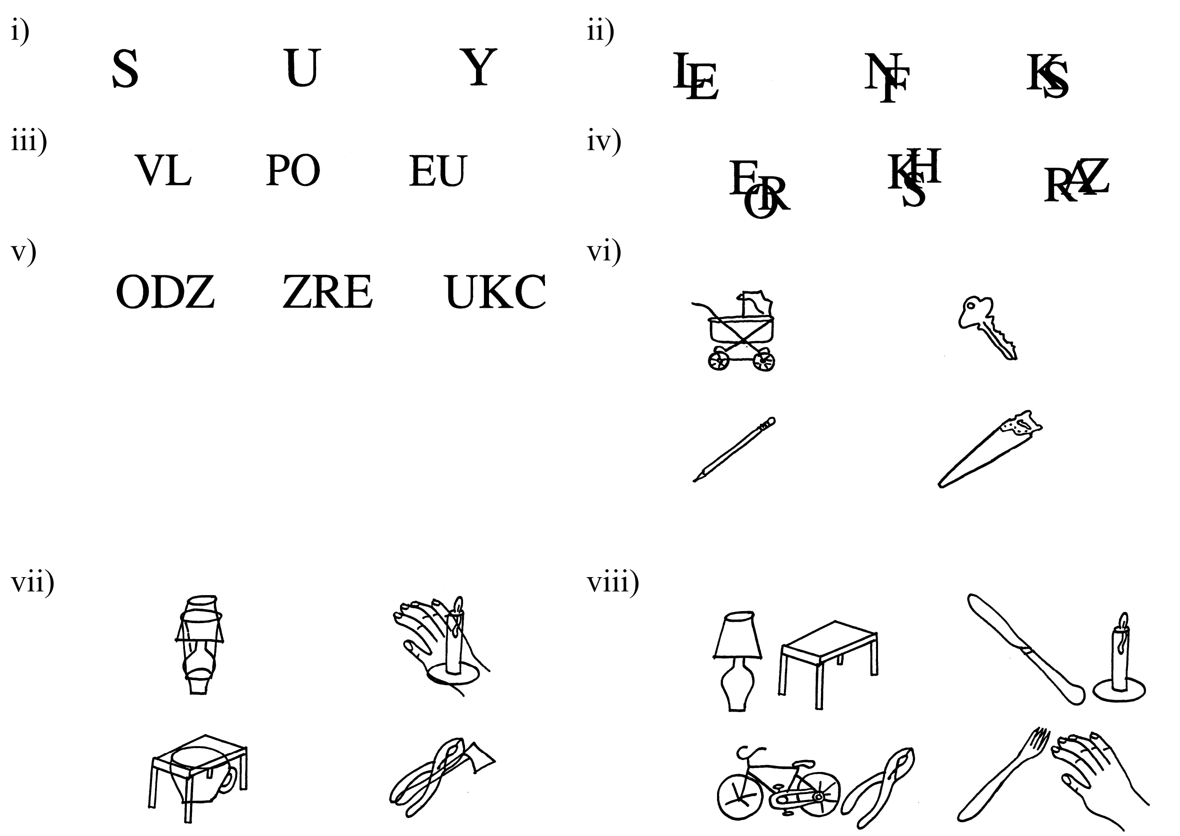
In the Identical Pictures subtest of the Kit of Factor-referenced Cognitive tests, the child is required to decide which of four picture options matches the target picture as quickly as possible. Each of the target pictures is an abstract image, with the options all being similar, in order to prevent the child being able to rely on naming the picture then searching for that same figure (see Figure 6). The child has two sections of 48 trials each and has one and a half minutes for each section, in which time the child aims to correctly complete as many as possible.

Figure 6: Three items of the Identical Pictures subtest of the Kit of Factor-Referenced Cognitive tests



The Birmingham Object Recognition Battery (BORB) consists of 14 subtests designed to assess aspects of visual processing and visual object recognition. In the current research two subtests were administered – the Minimal Feature View Task, and the Overlapping Figures subtest. The Minimal Feature View task involves 25 trials where three different pictures are presented for each trial – the top picture is of an object taken from a standard viewpoint, and the two lower pictures are a) the same object from a different viewpoint, in which some of the key visual features are obscured from view, and b) a different, but visually similar object. The subject is required to decide which of the two lower pictures shows the same object as the upper picture. The BORB overlapping figures subtest scores the time taken to identify visual images presented in five ways: i) individually; ii) in overlapping pairs; iii) in non-overlapping pairs; iv) in overlapping triplets; v) in non-overlapping triplets (see Figure 7). In one subtest all images are letters and in another subtest all images are line drawings. For the current research, the mean overall time each individual took to identify individual images (single and non-overlapping images) and the mean overall time taken to identify overlapping images (paired and triplet overlapping images) were compared.

Figure 7. The BORB Overlapping Figures subtest of i) individual letters, ii) overlapping pairs, iii) non-overlapping pairs, iv) overlapping triplets, v) non-overlapping triplets, vi) individual images, vii) overlapping images, viii) non-overlapping paired images.



2) Visual-Verbal and Verbal Tests. The visual-verbal tests comprised: Castles and Coltheart's (1996) Homophone Selection test; Olson, Forsberg, Wise and Rack's (1994) Orthographic Word-Pseudohomophone Choice task; the Sound Decoding, Sound Spelling, Sight Decoding and Sight Spelling subtests of the Illinois Test of Psycholinguistic Abilities – Third Edition (ITPA-3; Hammill, Mather & Roberts, 2001); and the verbal subtests comprised the Sound Deletion subtest of the ITPA, and the Word and Nonword Minimal Pairs and the Nonword Repetition subtests of the Psycholinguistic Assessment of Language Processing in Aphasia (PALPA; Kay, Lesser & Coltheart, 1992).

Castles and Coltheart's (1996) Homophone Selection test comprises three subtests assessing 1) Regular word/regular word homophone selection, for example bean/been 2) Regular word/irregular word homophone selection, for example, berry/bury and 3) Irregular word/nonword homophone selection, for example bald/borld. Each subtest comprises 30 pairs of homophones. In the Regular/regular and the Regular/irregular subtests each word in a homophone pair is matched to a simple descriptor, for example the accompanying descriptions for the word pair 'bean/been' were 'a green vegetable' and 'where have you __?' The Irregular/nonword subtest comprises 30 irregular words, a simple definition for each, a matched nonword, for example 'worry/wurry', as well as a visual foil – a nonword selected to be visually similar to the homophone nonword, for example 'warry'. Across the subtests, for each homophone selection the child is presented with a definition and required to select the matching word. For the Regular/regular and Regular/irregular subtests, the child is required to select the correct word from the homophone pair, and for the Irregular/nonword subtest the child is required to select the correct irregular word from the nonword and visual foil. For example, for the sentence 'to be concerned about something' the child is required to select 'worry' from the other options of 'wurry' and 'warry'.

In the Olson et al. (1994) Orthographic Word-Pseudohomophone Choice task, a word-nonword homophone pair (e.g. rain-rane) is presented and the child must select the real word as quickly as possible. There are 88 trials, 48 featuring short, high-frequency (e.g. take-taik, word-wurd, deep-deap), and 40 featuring longer, lower-frequency target words (e.g. muscle-mussle, studdy-study, nuisance-nusance).

In the ITPA Sound Decoding subtest (Hammill et al., 2001), the child must read a list of 25 phonically regular nonwords, which are presented as the names of make-believe creatures (e.g. Yang, Quiff, Durcle). The Sound Spelling subtest requires children to fill in the missing letters for a phonologically regular nonword. The examiner reads each word (e.g. "bling"), the child's form is printed with part of the word (e.g. 'b__') and the child then fills in the missing letters (e.g. 'ling'). There are a total of 25 items. In the Sight Decoding subtest, the child must read aloud a list of up to 25 printed irregular words. The Sight Spelling subtest follows an identical format to the Sound Spelling, but focusses on irregular words (e.g. the examiner reads "said" and the child must complete their form 's__d' by writing 'ai'). The ITPA sound deletion subtest requires the child to delete syllables and/or phonemes from spoken words, creating new words or nonwords (e.g. the examiner might ask the child to "say 'hold' without the 'h'", or to "say 'frame' without the 'fr'"). All subtests are discontinued following three consecutive errors.

The Word and Nonword Minimal Pairs subtests of the PALPA require the child to discriminate similarities and differences between 72 pairs of auditorally-presented real words (for example, 'tack-cat' and 'coat-coat') and 72 pairs of nonwords (for example 'put-tup', 'gak-gak'). The PALPA Nonword Repetition subtest requires the child to repeat 30 nonwords after they have been spoken by the experimenter. Ten of the nonwords are one-syllable (for example, 'splant'), ten are two-syllable (for example, 'drattle') and ten are three-syllable (for example, 'ality').

Procedure.

Each assessment session was conducted after school, either at the child's home, or, if this was not possible or appropriate, at School A's meeting room. The WISC-III was administered first, then the remaining tests were administered in the following order, varying slightly according to the time available for each session, and the time taken by the child to complete each test; Stanford-Binet Bead Memory test, PALPA Minimal Pairs tests and Nonword Repetition, Kaufman Gestalt Figures and Spatial Memory, BORB Minimal Features and Overlapping Figures subtests, BVRT – 5^{th} Edition, Castles and Coltheart (1996) Homophone Selection, Olson Orthographic Coding test, ETS Auditory and Visual Number Memory tests and Picture Matching, and finally, the ITPA subtests of Sound Deletion, Sight and Sound Decoding, and Sight and Sound Spelling.

With the exception of Castles and Coltheart's (1996) Homophone Selection test, all tests were administered according to standard procedure. The Castles and Coltheart (1996) Homophone Selection test was administered to the children over two sessions on the Apple Macintosh laptop using the PsyScope program (Cohen et al., 1993). Each description initially was presented on screen using Comic Sans 24-point font and was read aloud to the child, for example 'A green vegetable'. The child then pressed the space bar and the pair or trio of words and nonwords, for example 'bean/been' was presented underneath the description using Comic Sans 48-point font. The child was required to select the correct word by responding with a corresponding key press ('a' for the word presented on the left of the screen and 'l' for the word presented on the right). For the Irregular/nonword subtest when there were three options, the corresponding keys were 'a', 'g' and 'l'. Prior to beginning the test, and numerous times throughout, the child was requested to select the correct word as quickly as possible. The second session was separated from the first session by at least a week and involved the presentation of the remaining 30 descriptors for the Regular/regular and Regular/irregular subtests, for example ‘Where have you _?’ for the word pair ‘bean/been’. Across both sessions, the correct response was randomly positioned on the screen.

Results

Results from each participant are presented in Tables 3 to 5. For each table the results for the three surface dyslexics (MJ, ST and PS) are presented on the left-hand side and the results for the seven phonological dyslexics (WC, MT, KI, GM, PJ, TT and LJ) are presented on the right-hand side. As shown in Table 3, IQ levels, as determined by the WISC-III results, indicated that all children, both developmental surface and developmental phonological dyslexic, showed a lower Verbal IQ than their Performance IQ, with some children, such as PS, WC and MT, showing marked differences. It is also noteworthy than for many of the children, their Performance IQ was at, or above, average. MJ and ST attained Full IQ scores below what was expected from their Block Design subtest administered during Screening and Selection, where they attained scaled scores of 8 and 10 respectively.

Table 3 – see end

We will now take a cursory glance at the results from the Background Testing, however it is important to bear in mind the variation of IQ levels between the participants, which may potentially impact on the scores. Table 4 presents results from the Visual tests. The Benton Visual Retention test (BVRT) required children to reproduce designs from memory. Two scores are provided – the number correct attained by the child (out of 10) and the number of errors made (up to 24), along with the normed score for each child based on their IQ (from the child's WISC-III score). All the children attained number correct scores above the expected score level based on their IQ scores. For the error scores, the children all again scored at a higher level than their expected score, except for one of the phonological dyslexics, GM. Overall, on the BVRT, the phonological dyslexics achieved higher scores for the number correct, and lower error scores than the surface dyslexics, although there was considerable overlap between the two groups. This tendency for the surface dyslexics to achieve lower scores on visually-related tests was perhaps clearer with the Kaufman Gestalt subtest. On this test, where children are required to identify a degraded image, the surface dyslexics' scaled scores were all below normal (10). In comparison the scores for the phonological dyslexics ranged from 9 up to 14, with 5 of the 7 individuals scoring 10 (normal) or above.

Table 4 – see end

The range of scores achieved by the surface dyslexics on the Stanford-Binet bead memory subtest ranged from 39 to 51 (with 50 indicating normal). The phonological dyslexics averaged slightly higher, ranging from 47 to 60, with only minimal overlap between the two groups. On the ETS Identical Pictures subtest, where children must decide which of four picture options matches the target picture, the surface dyslexics scored slightly lower than the phonological dyslexics. On the BORB Minimal Features subtest, which involved matching objects that are shown from different viewpoints, all individuals, both surface and phonological dyslexics, scored at or near ceiling.

The BORB Overlapping Figures subtest assessed the time taken to identify letters and pictures, singularly and overlapping. The results presented are the mean time taken to read each letter or identify each picture when presented non-overlapping (single, paired and triplet). Then the difference between this time and the mean time taken to read each overlapping letter or identify each overlapping picture (paired and triplet). This is either positive (indicating a greater time taken) or negative (indicating a reduction in time). The phonological dyslexics generally took longer than the surface dyslexics to read the non-overlapping letters, however the increase in time with overlapping letters showed no particular trends with respect to dyslexia subtype. These scores were highly variable, particularly for the phonological dyslexics. For the non-overlapping pictures, the range of times taken by the surface and phonological dyslexics was comparable. Again the increase in time taken with the overlapping condition failed to show any consistent differences across subtypes.

For the Visual Number Span and the Auditory Number Span subtests, children were shown a series of numbered flashcards or read a list of numbers respectively, and then required to write down the series. Scores were determined according to the maximum length of numbers the child was able to recall (up to a maximum of 12). Both the phonological and surface dyslexics exhibited little difference between their scores on the visual and auditory number spans, apart from MT, who recalled a maximum of 0 on the auditory number span.

So, in sum, while the range of scores on most of the Visual tests was wide, there was indication that the surface dyslexics tended to score lower than the phonological dyslexics on some of the visual memory tests (the Stanford-Binet bead memory and the BVRT) and the Kaufman Gestalt subtest. It is of note that PS attained a low score on the Kaufman Gestalt; in this case IQ alone cannot account for this low score. However, overall, the slightly lower scores attained by the surface dyslexics on the visual tests was no more than a tendency; in none of the tests did the range of scores attained by the surface dyslexics fall completely outside the range attained by the phonological dyslexics.

Table 5 presents the results from the Visual-Verbal and the Verbal tests. Results for the Castles and Coltheart Homophone Selection test, across the four subtests, indicate no clear differences between the surface and phonological dyslexics. Results were similarly non-discriminating between the dyslexia subtypes for the Olson Homophone Choice test, where the child was required to select the real word from the nonword homophone. Both the highest and the lowest scores were attained by surface dyslexics.

Table 5 – see end

On the ITPA Sound Decoding subtest, where children had to read aloud regular nonwords, all individuals scored below the normal score for their age-group (scaled score of 10). For this test, there was a clear separation between the two dyslexia subtypes: the surface dyslexics scored between 8 and 9, while the phonological dyslexics all scored below this, with scores ranging from 3 to 7. The low scores attained by the phonological dyslexics are not surprising, as poor nonword reading ability was the key requirement for classification as phonological dyslexic. The ITPA Sound Spelling subtest, where the children were required to complete the spelling of phonically regular nonwords, also discriminated well between the two dyslexia subtypes. The surface dyslexics scored at normal or slightly above normal levels. In contrast, five of the seven phonological dyslexics achieved scores below normal. The Sight Decoding subtest required children to read aloud irregular words. Surprisingly, the surface dyslexics all scored as well as, or better than the phonological dyslexics, despite the fact that poor irregular word reading is a key requirement for classification as a surface dyslexic. The Sight Spelling subtest, which required children to spell irregular words, also failed to discriminate between the dyslexia subtypes. Finally, for the Sound Deletion subtest, where children are required to delete syllables or phonemes from spoken words, the results attained did not consistently discriminate between the two subtypes.

For the PALPA Word and Nonword Minimal Pairs discrimination subtests, and the PALPA Nonword Repetition subtest, all children, both phonological and surface, scored at, or near, ceiling. Of note is that MT, a phonological dyslexic, attained the lowest scores on all of the PALPA subtests, which is consistent with his poor Auditory Number Span.

Discussion

A number of findings from the Background Testing section are worthy of comment. Firstly, the administration of the full WISC-III revealed some surprising results. Despite having performed well on the Block Design subtest administered during the initial screening (see scores in Table 2), two of the surface dyslexics (MJ and ST) were identified as having low IQ (both Performance and Verbal IQ below 85) when the full WISC-III was administered. These low IQ scores need to be taken into account when assessing the performance of MJ and ST throughout Experiment 1, both in pretesting and in the training programmes.

Turning now to the visual tests: overall, the developmental surface dyslexics attained lower scores on three of the Visual skills tests; the Benton Visual Retention test (BVRT), the Stanford Binet Bead Memory test and the Kaufman Gestalt. The BVRT and the Stanford-Binet Bead Memory test both have a strong immediate visual memory component. The suggestion that surface dyslexics exhibit poor visual memory skills is consistent with previous research (Goulandris & Snowling, 1991; Samuelsson et al., 2000; Watson & Willows, 1993). The strongest difference between the scores attained by the dyslexia subtypes was for the Kaufman Gestalt test. This test assesses children's ability to view objects as configurations, rather than viewing an object as the combination of a number of components. This poor ability to focus on items as configurations may be viewed as consistent with the defining feature of surface dyslexia: the focus on words as combinations of sounds, with the continued reliance on breaking words down into separate sounds in order to read them, thereby inhibiting learning of irregular words. The poor ability to focus on items as configurations exhibited by the surface dyslexics is consistent with some of the early subtyping research; Boder (1971) identified a group of dyslexics as 'dyseidetic' – characterized by slow reading and focussing on sounding-out each word (characteristics of surface dyslexia). Another name Boder gave this group was 'Gestalt-blind' as they have a lower-level sight vocabulary than other readers, and sound out words rather than using whole-word visual Gestalts. Using this subtyping approach, Bayliss and Livesey (1985) also found that dyseidetics had poor visual memory and, in visual sequential memory tasks, dyseidetics processed words and pictures serially rather than spatially. The findings of the current research provides further support for the idea that dyseidetic/surface dyslexics focus on the individual components of each word/picture, rather than focussing on the overall image.

However, the hypothesis that visual difficulties would be associated with developmental surface dyslexia was not consistently supported. On some of the Visual skills tests – the BVRT, BORB Minimal Features and the BORB Overlapping and Non-overlapping figures tests, there was no difference between the scores attained by the surface dyslexics and the phonological dyslexics. And, although MJ and ST (two of the surface dyslexics) attained the lowest scores on the Kaufman Gestalt, Stanford-Binet bead memory and the ETS Identical Pictures test, PS, the other developmental surface dyslexic did not score below the developmental phonological dyslexics on these tests. It is possible that the relatively low IQ scores of MJ and ST may have been a contributing factor to their lower scores on these Visual tests. However, the fact that ST and MJ did not score noticeably below the other children on the Visual-Verbal or the Verbal tests, despite their lower IQs, suggests that these low scores on the Visual skills tests may be related to developmental surface dyslexia. Due to the surface dyslexics attaining lower scores on the majority of the visual skills tests than the phonological dyslexics, the hypothesis that visual difficulties and developmental surface dyslexia would be related was not clearly refuted either, indicating that further research is required to fully investigate the presence of any relationship. The results attained in the current research suggest that the Kaufman Gestalt test may warrant further research as a promising test to investigate potential visual difficulties associated with surface dyslexia.

Some of the Visual-Verbal tests discriminated effectively between the dyslexia subtypes with the phonological dyslexics attaining lower scores, whereas other subtests did not. Generally, those tasks involving nonwords were consistently completed more poorly by the phonological dyslexics than the surface dyslexics, whereas tasks involving irregular words failed to show divergence between the subtypes. Other than the Sound Deletion subtest, no differences were observed on any of the Verbal tests – however this may primarily be due to all the children scoring at, or near ceiling.

It is surprising that, on the Sound Decoding subtest, which examines nonword reading, although the test discriminated between the two dyslexia subtypes (with the phonological dyslexics scoring below the surface dyslexics), all the children scored below normal. This was the case despite the surface dyslexics all scoring within the ‘Normal’ band on nonword reading in the Coltheart and Leahy wordlists. This lower phonological ability is consistent with some research that has argued that all dyslexics, regardless of subtype, have poor phonological abilities, when compared with age-matched normal readers (Manis et al., 1993, 1996; Wilding, 1989). However, on the ITPA Sound Spelling subtest, which requires individuals to spell nonwords, the surface dyslexics all scored at or above average, whereas the majority of the phonological dyslexics scored below average. This difference between the dyslexia subtypes in phonological ability related to spelling, suggests that different elements of phonological skill may be required for reading and for spelling nonwords. This difference may be related to the production of GPCs (spelling nonwords) versus the processing of GPCs (reading nonwords).

A lack of difference was observed between the two subgroups' scores on the ITPA Sight Decoding and Sight Spelling subtests, which assess the pronunciation and written spelling of irregular words. The equal scores of the phonological and surface dyslexics on these subtests are of interest, as it would be expected that the surface dyslexics would achieve lower scores, due to irregular word reading representing their key area of difficulty. All individuals, both phonological and surface dyslexics, scored below normal (less than 10) on these tests, indicating that both phonological and surface dyslexics exhibited poor irregular word reading skills. In order to be selected for the study, the phonological dyslexics were required to exhibit weak nonword reading but relatively well-developed irregular word reading in the pretesting phase. However, four out of the seven developmental phonological dyslexics in the current study achieved this requirement by scoring Band A (definite deficit) in Coltheart and Leahy's (1996) nonwords, and Band B (borderline) for irregular words. It is also of note that the absolute scores attained by the phonological and surface dyslexics for irregular word reading do not show much variance.

It is of further interest that both phonological and surface dyslexics scored at a similar, relatively high level on the various homophone selection tests; Castles and Coltheart Homophone Selection and the Olson Homophone Choice tests. These high scores are not consistent with previous research, which has found that surface dyslexics generally exhibit lower ability on homophone selection tasks than control subjects (Castles & Coltheart, 1996). There has not been research comparing the results of phonological and surface dyslexics on homophone selection tasks. The relatively high scores of the phonological and surface dyslexics may have resulted from the use of higher frequency words, for example 'shoe', 'said', 'head', which, by the age of 12 years, children would often have been exposed to.

In summary, our background testing of participants found two overall differences between the two dyslexia subgroups. The surface dyslexics attained lower scores on some of the visual skills tests, indicating a potential correlation between surface dyslexia and visual difficulties. The phonological dyslexics attained lower scores on some of the tests assessing nonword reading, which would be expected as this is a primary difficulty associated with phonological dyslexia. Any conclusions about the two groups and any observed differences between them, are limited primarily by the small number of surface participants involved, and the low IQ of two of them; MJ and ST. Future research would benefit from a greater number of surface dyslexic participants, and matched abilities between the two groups.

Chapter 3: Experiment 1 – Training Programmes

Method

Participants.

The children who completed the Background Testing continued with the training programmes.

Overall Training

Method

Materials.

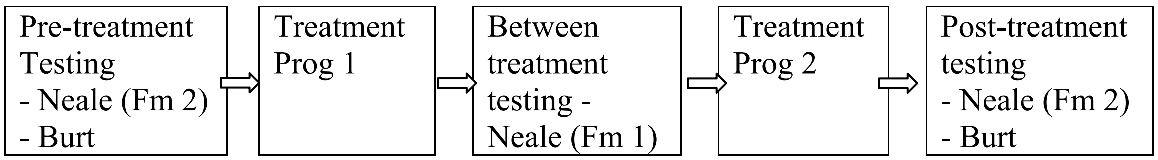
Pre-treatment and post-treatment reading ability was assessed using the Burt Word Reading Test and the Neale Analysis of Reading Ability. In the case of the Neale, Form 2 was used for both pre- and post-treatment testing and Form 1 was administered between the two treatment programmes.

Procedure.

Pre-training testing, training and post-training testing sessions began approximately one month after completing background testing, and were conducted individually for each child. Each child completed two sessions a week; one session during school time at a time determined by the classroom teacher, and one session after school, either directly after school in School A's meeting room, or, following that, at the child's home.

At the end of each session throughout the reading programmes, each child received a treat-sized chocolate bar and bag of potato chips. At the completion of both programmes, the families were sent a gift voucher to give to the child and some basic results of what their child had achieved (the percentage of words the child was reading prior to, and following completion of the training programmes, and their completion results). Information was also provided to the teachers and principals of the schools and the researcher visited each school to enable staff to discuss the results and ask any questions.

For the Training Programmes in Experiment 1, the children completed the following procedure:



The order the children completed the Phonological and Whole-word Training Programmes was counterbalanced, with half the children completing the Phonological Training Programme first followed by the Whole-word Training Programme, and the other half completing the Whole-word Training Programme first (see Table 6). Prior to beginning their first reading programme, each child completed the Burt Word Reading Test and the Form 2 version of the Neale Analysis. After completing their first remediation programme, each child then completed the Form 1 version of the Neale Analysis. After completing both programmes each child was readministered the Burt Word Reading Test and the Form 2 version of the Neale Analysis.

Table 6

Order of Programme Completion (surface dyslexics are in italics)

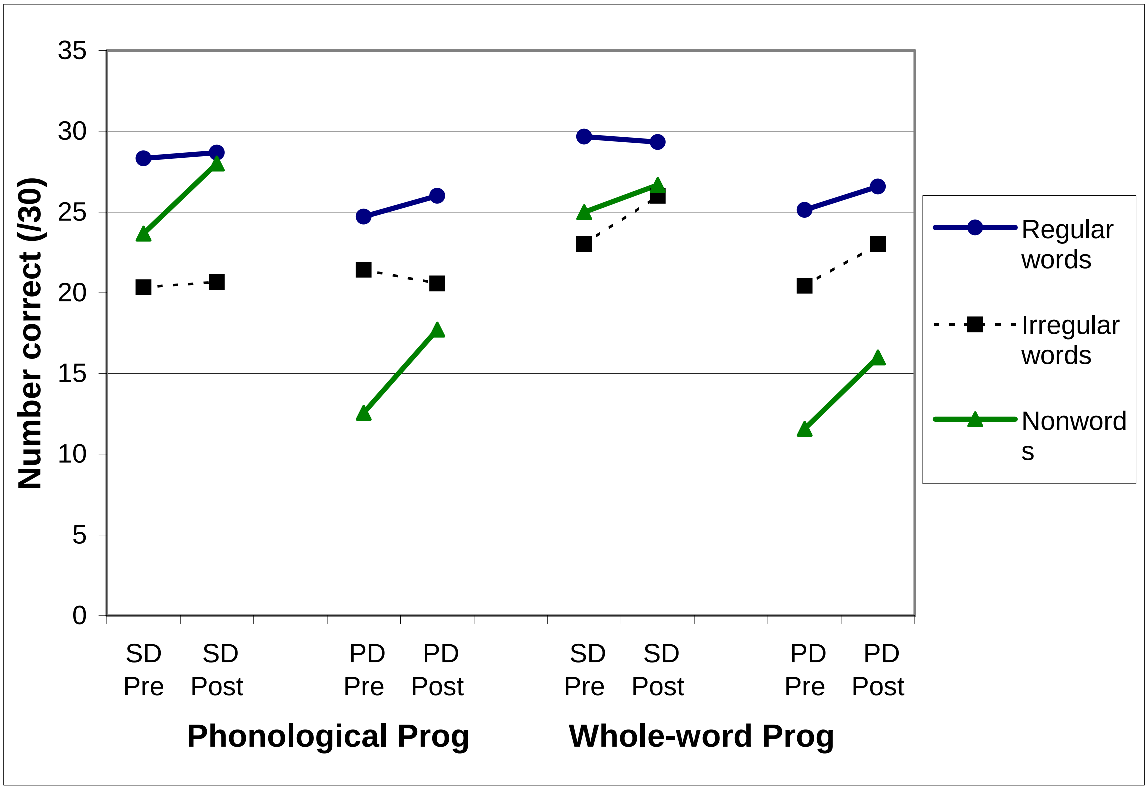
1. Phonological Programme 2. Whole-word Programme	1. Whole-word Programme 2. Phonological Programme
PS	*ST*
MJ	LJ
WC	KI
TT	MT
PJ	GM

Results comparing generalisation across treatment programmes

The scores for the Coltheart and Leahy wordlists (administered pre- and post-completion of the Phonological Training Programme) and the Alternative Wordlists (pre- and post-Whole-word Training Programme) are presented together in Table 7. Overall results have been presented, then the scores have been divided into developmental phonological dyslexics (n=7) and developmental surface dyslexics (n=3). These results are also presented below in Figure 8. A cursory examination of the figure and table means reveals the following tendencies. For the surface dyslexics, regular and irregular word reading appeared stable following the Phonological Training Programme, while their nonword reading improved. In comparison, the phonological dyslexics showed a slight improvement in regular word reading and a very slight decrease in irregular word reading following the Phonological Training Programme, while their nonword reading showed a notable improvement. Following the Whole-word Training Programme, both the surface dyslexics and the phonological dyslexics showed a slight improvement in their irregular word scores, with the phonological dyslexics again showing a greater improvement in their nonword reading scores.

Table 7 – see end

Figure 8. Scores for the surface dyslexics (SD) and phonological dyslexics (PD) on the Coltheart and Leahy Wordlists (Phonological Training Programme) and the Alternative Wordlists (Whole-word Training Programme), pre- and post- completion of the training programmes.



A four-way mixed between-within subjects analysis of variance (ANOVA) was performed on this data. The independent variables were Testing Phase (Pre- or Post-training programme), Word Type (regular, irregular and nonword), Programme Type (Phonological and Whole-word) and Subtype (phonological or surface dyslexia). For the whole participant group (both phonological and surface dyslexics combined), there was a significant main effect of Testing Phase; [$F(1,8)=18.83$, $p<0.01$], with a large effect size (eta squared=0.70), indicating that, on the overall wordlists, children performed better following completion of the training programmes, rather than at pre-test. The main effect of Wordtype also reached significance [$F(2, 8)=19.28$, $p<0.01$], as did the main effect of

Subtype [$F(1, 8)=11.07$, $p<0.05$], both with large effect sizes (eta squared=0.70 and 0.58, respectively). The data suggests that the nonword scores were significantly lower than the other wordtypes, with phonological dyslexics attaining significantly lower overall scores than the surface dyslexics. The interaction between Testing Phase and Wordtype reached significance [$F(2, 8)=11.02$, $p<0.01$], suggesting that, following completion of both training programmes, the nonword scores improved significantly more than the other wordtypes. The interaction between Wordtype and Subtype also reached significance [$F(2, 8)=5.99$, $p<0.05$], suggesting the phonological dyslexics attained significantly lower nonword scores than the surface dyslexics. The interaction between Programme Type and Subtype neared, but did not reach significance [$F(1, 8)=4.57$, $p=0.07$]. The three-way interactions did not reach significance: Testing Phase, Wordtype and Subtype [$F(2, 8)=0.10$, $p=0.76$], Testing Phase, Programme Type and Subtype [$F(1, 8)=0.08$, $p=0.80$], Wordtype, Programme Type and Subtype [$F(2, 8)=0.19$, $p=0.68$] and Testing Phase, Wordtype and Programme Type [$F(2, 8)=1.54$, $p=0.25$], and nor did the four-way interaction [$F(2, 8)=0.25$, $p=0.63$], indicating there was no significant difference between improvements made by the two dyslexia subtypes between the two programmes.

A three-way ANOVA was performed on the phonological dyslexics data, with the independent variables of Testing Phase, Wordtype and Programme Type. Testing Phase was found to have a significant main effect [$F(1,6)=28.75$, $p<0.01$] with a large effect size (eta squared=0.83), indicating that the phonological dyslexics' scores on the wordlists significantly improved after completion of each of the programmes. The main effect of Wordtype was also significant [$F(2, 6)=30.63$, $p<0.01$], with a large effect size (eta squared=0.84). The data in Table 7 suggests that the nonword scores were significantly lower than the regular and irregular word scores. Programme Type was not found to have a main effect [$F(1, 6)=0.64$, $p=0.46$] for the phonological dyslexics. The interaction between

Wordtype and Testing Phase reached statistical significance [$F(2,6)=16.90$, $p<0.01$], suggesting that the nonword scores significantly improved more than the other wordtypes following completion of both training programmes. The interaction between Testing Phase and Programme Type was not significant [$F(1, 6)=0.41$, $p=0.55$], nor were the interactions between Wordtype and Programme Type [$F(2, 6)=2.44$, $p=0.17$], and the three-way interaction between Programme Type, Testing Phase and Word Type [$F(2, 6)=0.38$, $p=0.56$]. Due to the number of surface dyslexics being so low (n=3), their scores have not been further analysed as the low number does not have enough power.

Table 7 – see end

Reading ability results

Throughout the programmes the children completed the two forms of the Neale Reading Analysis and the Burt Reading Test. The overall results of intervention on reading ability scores are presented in Table 8, with the children's scores attained from the initial and final Burt and Neale administrations, as well as the between-programmes administration of the Neale. Prior to beginning the first reading programme, the children completed Neale 1 and Burt 1. At this point, all children exhibited a reading age between one and four years behind for the Burt Reading test, and between two and five years behind their chronological age on the Neale Analysis accuracy score. Surface dyslexics' and phonological dyslexics' scores showed a similar range. As the training programmes focussed on training single word reading, rather than text reading, the Burt is a more appropriate assessment of the targetted skills. The Burt Word Reading test was re-administered at the completion of both training programmes (approximately three months after the first administration), and the surface dyslexics showed good overall improvement.

Scores improved between six months and more than one year ten months (one individual reached ceiling on the reading age ratings). The phonological dyslexics also exhibited general improvement greater than the three months accounted for by elapsed time – score improvements on the Burt ranged from six months to one year and five months. The same form of the Neale Analysis was administered to all children following completion of both the training programmes. On this assessment, one of the surface dyslexics showed only three months improvement on the Neale Analysis, as would be expected given the time that had passed. This individual thereby indicates no improvement from the training programmes. However, the other two surface dyslexics exhibited greater improvement, with their accuracy scores improving between one year and three months, and two years. The phonological dyslexics also showed a variety of results, ranging from a decline of two months to an increase of ten months in reading age. The results for both the surface and phonological dyslexics on these two reading tests suggest that, overall, the general reading ability of the surface dyslexics improved slightly more as a result of the training programmes, than did the phonological dyslexics reading ability.

Table 8 – see end

Examination of the participant's reading ability scores, according to order of training programme (noted by the letters next to their name) indicate that similar results were attained following both training programmes. Following the Phonological Training Programme two of the three surface dyslexics and six of the seven phonological dyslexics showed an improved reading age score, with the highest improvement attained by ST; an improvement of over two years. The Neale results following the Whole-word Training Programme are similar, with small improvements and some slight decreases in reading age.

Teacher/parent evaluations of reading improvement.

Although no overall improvements in reading ability were demonstrated in the post-test data, the children, and their teachers and parents, commented that they had observed improvement in the children's reading and confidence. The following quotes were provided by some parents and teachers as feedback following the treatment programmes;

"(His) reading has improved dramatically. Improvements (have been observed) across the curriculum in maths, science and social studies. Increased confidence level. (TT)"

"His confidence in group discussions has improved. (PS)"

"Over the year (she) has worked more independently in written work. Comprehension improved. Spells out words more confidently. (ST)"

"(His) confidence and word attack skills have increased dramatically. (KI)"

"She's more confident about what she has read – evident in all curriculum areas. (WC)"

"We'd really like to thank you for your very positive influence on (him) and his reading skills. He got his report today and saw that in this half of the year he has gone up two levels in his reading – he has said that he is really pleased that he has done the extra reading. (PJ)"

Phonological Training Programme

Method

Materials.

Pre-programme reading performance was assessed using Coltheart and Leahy's wordlists (1996). Also, the child's knowledge of the phonemes of the English language was examined using Lovett et al.'s (1994) 'Sounds' component of the Phonological Analysis and Blending/ Direct Instruction (PHAB/DI) Reading Training Program. In this task, for each phoneme the child is presented with a simple word and is asked to produce the sound of a particular letter, e.g. “What do the letters ‘s’ ‘h’ sound like in the word ‘ship’?” (Appendix G). This procedure is conducted for each of the 40 most common phonemes in the English language.

To establish the grapheme-to-phoneme correspondences (GPCs) that the child was having most difficulty with (their target training GPCs), a GPC Selection test was constructed. This comprised a list of words and nonwords, adapted from Broom and Doctor’s (1995b) Second List of Regular Words (Appendix H). The original list from Broom and Doctor contained 5 examples of each of the 20 most frequently occurring GPC mappings involving vowel and consonant digraphs (as illustrated below in Table 9). All the words were of low frequency (less than 10 per million, according to Carroll et al., 1971) to ensure they were unlikely to be represented in the child’s visual lexicon. In the current research, this list was extended to include nonwords: five nonword examples of each of the 20 target GPCs. The nonwords were individually matched with a corresponding regular word, in terms of letter length and syllable length, differing in 1 or 2 letters only. As in the original Broom and Doctor list, several words contained more than one of the assessed GPCs, so the total number of actual words and nonwords presented was slightly less than 200 (171 in total). However, each of the 200 examples of GPCs was scored individually, so the total score was out of 200.

Table 9.

Twenty Most Common Digraph Grapheme-to-Phoneme Correspondences (‘_’ represents another letter in the space) and word examples.

‘AI’	frail	‘AU’	haunt
‘AY’	stray	‘A_E’	rate
‘CH’	chat	‘CK’	stack
‘EA’	bleat	‘EE’	creep
‘IE’	thief	‘I_E’	vine
‘LE’	jingle	‘NG’	jingle
‘OA’	moat	‘OO’	scooter
‘OW’	marrow	‘O_E’	dome
‘PH’	phone	‘QU’	quick
‘TH’	third	‘U_E’	tune

The child’s scores on the GPC Selection test were used to identify their 10 lowest scoring GPCs. Once these had been identified, a set of training words was compiled, featuring 10 word and 10 nonword examples for each of their 10 weakest GPCs. All of the words had a frequency of less than 10 per million (Carroll et al., 1971) and none of the words or nonwords were featured on the GPC Selection test.

Procedure.

The Phonological Training Programme began with administration of the Coltheart and Leahy (1996) 90-item wordlist, presented to the child using PsyScope on the Apple Mac laptop computer, with 48-point Comic Sans font. The child determined the speed with which words were presented by pressing the space bar each time to bring up the next word. Each word was accompanied by a ‘beep’, which enabled the onset of the word presentation to be clearly identified. A tape recorder was used to record the child’s response to each word, and the tapes were later used to time how long it took for the child to respond after the word was presented (the beep).

Following this, the 40 phonemes from Lovett et al.'s (1994) PHAB/DI programme were then presented to the child on the laptop, with the key grapheme presented on the left side of the screen (in 100-point Comic Sans font) and its corresponding word presented simultaneously on the right side of the screen (80-point font). The experimenter explained to each child that a few letters would appear on the left-hand side of the screen and a word with those letters in it would appear on the right-hand side. The child was required to state the sound of the grapheme in the given word, for example "What do the letters 's' 'h' sound like in the word 'ship'?"

No child had difficulty correctly pronouncing the graphemes so all children then progressed to reading the GPC Selection test. The regular words and nonwords were presented individually in a random order, using Comic Sans 48-point font. As with the presentation of Coltheart and Leahy's (1996) wordlists, each word and nonword was presented with a corresponding 'beep'. Responses were recorded, and the tapes were later used to determine the time taken for the child to identify each word. The results from the GPC Selection test determined each child's ten target training GPCs – the ten GPC sets the child attained the lowest scores for (out of 20 – 10 regular words and 10 nonwords).

The child was presented with a different GPC each training session, starting with the GPC yielding the lowest score (where scores were equal, the most common GPC, according to Berndt, Reggia and Mitchum, 1987), was selected first). Each session began by focussing on the real words in the training set (recall that the training set contained 10 real words and 10 nonwords for each target GPC). Beginning with the word of highest frequency, each word was read aloud by the experimenter, repeated by the child and defined if necessary. The child then attempted to spell the word on a magnetic board using plastic magnetic letters. The child focussed on sounding the word out whilst spelling it, and was helped by the experimenter sounding the word out slowly and focussing their attention on key areas of the word if they were having difficulty. The child then wrote the word into their exercise book, sounding out each letter again while writing it. Spelling could be checked against the plastic letters on the board if the child was unsure. After completing this process for the 10 real words, the child then followed the same steps for each of the nonwords, but was informed they were nonwords. Throughout the learning of each real word and nonword, the child was encouraged to identify real words with similar spellings, e.g. for the word 'snail', the child might change some of the plastic letters to make it 'hail' 'wail' etc, for the nonword 'launt' the child may identify 'haunt' 'laundry' etc. After all target words and nonwords for a particular GPC had been worked on, the child was dictated a sentence combining at least 5 of the targetted real words, e.g. for the GPC 'AU' – 'The naughty girl felt daunted when the gaunt man at the laundry started to taunt her' (Appendix M). The child wrote this in their exercise book also. At the start of each subsequent session the child revised the previously taught GPCs by reading each sentence and identifying the GPC and its corresponding sound.

At the completion of the ten sessions of the Phonological Training Programme, the children again completed the GPC Selection test, which did not contain any of the trained words or nonwords. Coltheart and Leahy's (1996) wordlists was also readministered, with the responses to both tests tape recorded.

Results

Results following completion of the Phonological Training Programme are presented in Table 10. The table presents the scores from the GPC Selection test, for both Testing Phases (pre- and post-programme), out of a total of 200 – 5 regular word and 5 nonword examples for each of the 20 GPCs. Target training GPC scores and Nontarget GPC scores are also presented; how the child scored in the GPC Selection test on their 10 identified target GPCs (out of 100), and their 10 nontarget GPCs (/100) in both testing phases.

Table 10 – see end

All children improved their GPC awareness as a result of the Phonological Training Programme. A three-way mixed between-within subjects analysis of variance (ANOVA) across subjects was conducted to explore the impact of Testing Phase (pre- or post-completion of the Phonological Training Programme), Target Status (whether the item contained a trained GPC or not) and Subtype (whether the individual was a surface or phonological dyslexic) on the children's scores on the full GPC Selection test. There was a statistically significant main effect for Testing Phase [$F(1, 8)=30.02$, $p<0.001$], Target Status [$F(1, 8)=148.63$, $p<0.001$] and Subtype [$F(1, 8)=9.04$, $p<0.05$], all with large effect sizes (eta squared=0.81, 0.95 and 0.53, respectively). The mean scores presented in Table 10 indicate that significantly higher scores were attained post-training rather than pre-training, on Target GPCs rather than non-Target and by the surface dyslexics compared to the phonological dyslexics. The interaction between Testing Phase and Target Status was highly significant [$F(1, 8)=69.00$, $p<0.001$], with a large effect size (eta squared=0.90), indicating that the reading of words and nonwords containing trained GPCs improved significantly more following completion of the Phonological Training Programme than did the reading of items containing untrained GPCs. The interaction between Testing Phase and Subtype was also significant [$F(1, 8)=5.90$, $p<0.05$]. This suggests the phonological dyslexics improved significantly more than the surface dyslexics on the full GPC Selection test, possibly influenced by the lower base rate attained by the phonological dyslexics. The interactions between Subtype and Target Status [$F(1, 8)=3.00$, $p=0.12$] and the three-way interaction between Testing Phase, Target Status and Subtype [$F(1, 8)=1.47$, $p=0.26$] did not reach statistical significance.

Two-way ANOVAs were conducted to evaluate the impact of Testing Phase and Subtype on the children's separate scores for their target training GPCs, compared to their non-target. For the target GPCs alone, there was a statistically significant main effect for Testing Phase [$F(1, 8)=184.57$, $p<0.001$], with a very large effect size (eta squared=0.96), indicating scores significantly improved following intervention. There was also a statistically significant main effect for Subtype [$F(1, 8)=9.74$, $p<0.05$], again with a large effect size (eta squared=0.55). The mean scores presented in Table 10 indicate that, regardless of Testing Phase, the phonological dyslexics attained significantly lower scores than the surface dyslexics. The interaction effect between Testing Phase and Subtype also reached statistical significance [$F(1, 8)=16.14$, $p<0.01$], with a large effect size (eta squared=0.67). The data suggests that the phonological dyslexics improved significantly more on reading words and nonwords containing their target GPCs following the Phonological Training Programme, than did the surface dyslexics. Again, this is possibly influenced by the lower base rate scores attained by the phonological dyslexics.

For the non-target GPCs, there was a statistically significant main effect for Subtype [$F(1, 8)=6.84$, $p<0.05$] with a large effect size (eta squared=0.46). The mean scores indicate that, as with the Target GPCs, the surface dyslexics attained significantly higher scores than the phonological dyslexics. The main effect for Testing Phase did not reach statistical significance [$F(1, 8)=0.96$, $p=0.36$] and nor did the interaction effect [$F(1, 8)=1.56$, $p=0.25$]. The lack of a significant main effect for Testing Phase indicates that the Phonological Training Programme did not significantly generalise to improve the overall skills at reading words and nonwords containing untrained GPCs. However, some generalisation was observable for three of the phonological dyslexic participants: PJ, MT and LJ, who showed clear numerical improvement on their nontarget GPC scores (see Table 10). The highest numerical improvement, both for the target and nontarget GPCs, was shown by PJ, a phonological dyslexic.

Phonological training programme generalisation results

Generalisation was further assessed using the results from the Coltheart and Leahy wordlists administered pre- and post-Phonological Training Programme (presented in Table 11). Following completion of the Phonological Training Programme, all children, both surface and phonological dyslexics (except for TT), exhibited numerical improvements on reading the nonword wordlist. For some of the children (particularly some of the phonological dyslexics), these improvements in nonword reading appear substantial, for example MT's nonword score improved from 1 correct up to 9, GM from 15 to 23, LJ from 10 to 18. Some scores for regular word reading also improved, such as KI from 23 to 26, and GM from 23 to 28, which could also support generalisation. However, regular word improvements were not achieved by the majority of the children and were not to the extent and degree of the nonword reading improvements. There were no improvements in the irregular word reading scores, for either surface or phonological dyslexics.

Table 11 – see end

A three-way mixed between-within subjects ANOVA was conducted to explore the impact of Testing Phase, Subtype (phonological or surface dyslexic) and Wordtype (regular, irregular or nonword) on the scores attained by participants on the Coltheart and

Leahy wordlists. There were statistically significant main effects for Testing Phase [$F(1, 8)=5.88$, $p<0.05$] and Subtype [$F(1, 8)=9.13$, $p<0.001$], with large effect sizes (eta squared=0.42 and 0.53, respectively). The mean scores indicate that the overall scores increased significantly following training, with the scores attained by the surface dyslexics significantly higher than those attained by the phonological dyslexics. The main effect of Wordtype was also significant [$F(2, 8)=17.97$, $p<0.01$], with a large effect size (eta squared=0.69). This appears to be due to lower overall performance on nonwords than on regular or irregular words. The interaction between Subtype and Wordtype was also statistically significant [$F(2, 8)=6.17$, $p<0.05$]. As shown in Table 11, this is likely to be due to the surface dyslexics having attained higher scores than the phonological dyslexics for both the regular and nonwords. The interaction between Testing Phase and Wordtype [$F(2, 8)=20.39$, $p<0.01$] reached statistical significance, suggesting that the nonword scores improved significantly more than the other wordtypes following intervention. The interaction between Testing Phase and Subtype [$F(1, 8)=2.23$, $p=0.17$] and the three-way interaction [$F(2, 8)=0.01$, $p=0.94$] did not reach statistical significance.

The mean reading times taken by each individual to read the Coltheart and Leahy wordlists, before and after completion of the Phonological Training Programme, are presented in Table 12. The differences between the times are presented for each individual, as well as group means for the surface and phonological dyslexics. The times presented are only for the words that were read correctly both before and after the completion of the Phonological Training Programme. The group means indicate that, overall, the surface dyslexics took less time to read all three wordlists after completing the Phonological Training Programme than they had prior to programme completion. In comparison, the phonological dyslexics, overall, took a longer time to read each of the three wordlists after completing the Training Programme. A three-way mixed between-within subjects ANOVA was conducted to explore the impact of Testing Phase, Subtype and Wordtype on reading times. There was a statistically significant main effect for Wordtype [$F(2, 8)=7.67$, $p<0.05$], with a large effect size (eta squared=0.49). The data in Table 12 indicates that nonwords were read significantly more slowly than the regular and irregular words. The main effect for Subtype did not reach significance [$F(1, 8)=1.06$, $p=0.33$], and nor did the main effect for Testing Phase [$F(1, 8)=0.56$, $p=0.48$), indicating the scores did not significantly improve following intervention. None of the interactions reached significance: Testing Phase and Wordtype [$F(2, 8)=0.51$, $p=0.49$], Testing Phase and Subtype [$F(1, 8)=2.76$, $p=0.14$], Wordtype and Subtype [$F(2, 48)=1.30$, $p=0.29$] and the three-way interaction [$F(2, 8)=1.05$, $p=0.34$]. These results indicate that completion of the Phonological Training Programme did not significantly alter the reading times for any of the wordtypes, for either of the dyslexia subtypes.

Table 12 – see end

Whole-word Training Programme

Method

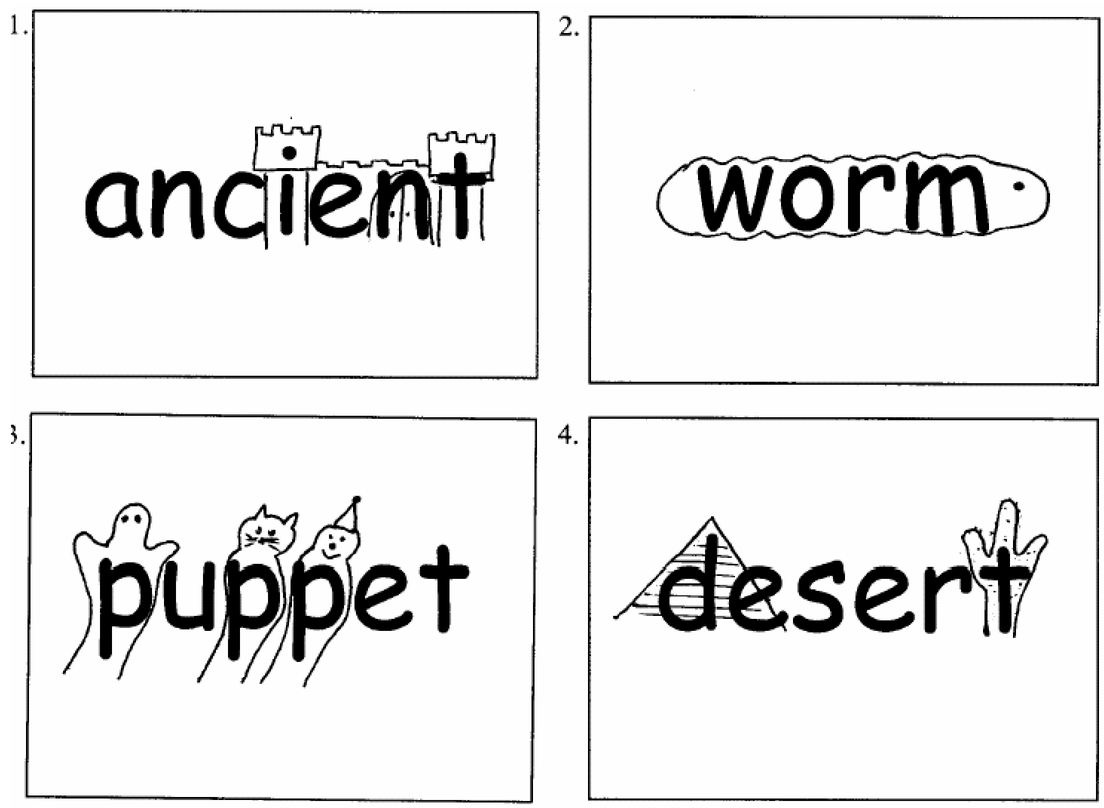
Materials.

Pre-programme reading performances were assessed using an alternative version of Coltheart and Leahy's (1996) wordlists. This Alternative Wordlist comprised three sections i) 30 regular words which were matched with Coltheart and Leahy's (1996) original 30 regular words on the basis of letter length, number of syllables and word frequency (Carroll et al., 1971); ii) 30 irregular words, selected to be close in frequency as the original irregular words, and iii) 30 nonwords, matched in key letter sounds to the original list of nonwords (see Appendix I).

To determine the appropriate words for training in the Whole-word Training Programme, two further lists of words were used. The first was based on Broom & Doctor's (1995a) list of 144 Irregular Words – the Irregular Word Selection test (Appendix J). The second was a list of regular words, which matched the irregular words in frequency (Carroll et al., 1971) – the Regular Word Selection test (Appendix K). Each child's training set of words was selected based on their performance on these tests: details appear in Procedure below.

In the Whole-word Training Programme, a series of visual mnemonic flashcards was developed. The cards were A7 in size and each features a word from the training set, with a related illustration drawn around the word. The illustrations emphasised the shape of the letters, and related the shape to the meaning of the word wherever possible (see Figure 9, with further examples in Appendix L).

Figure 9: Visual Mnemonic Flashcards for Whole-word Training Programme. Cards 1 and 2 show irregular words and cards 3 and 4 show regular words.



Procedure.

Prior to beginning the Whole-word Training Programme, the children completed the Alternative wordlists, and their responses were tape recorded. To determine the appropriate irregular and regular words, the child completed the Irregular Word Selection Test (Broom & Doctor, 1995a) and the matched Regular Word Selection Test, discontinuing each test after three consecutive errors. The child’s training list was developed to include any earlier errors, then including words from the cut-off point until a total of 50 irregular and 50 regular words were selected. The selected regular and irregular words were of a similar frequency, with the target frequency determined by the level attained on the Irregular Word Test. Prior to beginning the first training session, each child was presented with any of the selected training words that they had not encountered in the Irregular and Regular Word Selection pre-tests, to determine their pretraining reading accuracy.

Over the following ten training sessions, the child was introduced to 5 new irregular and 5 new regular words from their training lists each session, beginning with the words of highest frequency. The training procedure for each word was as follows. The child was initially requested to read a flashcard with the word written on it. The child was encouraged to try and read the word (‘have a go’) and if the child read the word incorrectly, or failed to produce a response, it was read to them by the teacher. The child was then asked to give the meaning of the word, and if they were unsure of the definition, they were asked to look the word up in a dictionary, then read the definition to the teacher.

The child was then presented with a visual mnemonic flashcard containing the written word combined with a meaning-related illustration emphasizing the wordshape (Figure 9, further examples in Appendix L). The visual mnemonic was discussed with the child, in relation to the meaning of the word, and the child was then requested to spell the word on the board with the plastic letters, without looking at the flashcard. The child then wrote the word in their exercise book.

After all of the ten target words for the training session had been introduced, the child then completed a Cloze task based on the words. The child was asked to read a sentence fragment presented on the upper half of a computer screen, with a word missing within the sentence e.g. ‘The rich family lived in a __’ (presented in Comic Sans 24-point font). 3 seconds following the presentation of the sentence, four word options were presented below the sentence – the correct word, and three other words (sometimes including a nonword), which were of a similar length and involved similar letters to the correct word (Comic Sans 48-point font) e.g. ‘mention   pension   mansion   manchin’. The child was asked to select the correct word-option as quickly as possible, by pressing the key corresponding to the word's screen position (a, f, j, ;). Each session involved 3 sentences for each of the target words of the session and 6 sentences from previous sessions (36 sentences in total).

Following this, the child completed a word identification task based on degraded images of each word. Using the PsyScope programme (Cohen et al., 1993), individual words were presented on the computer screen in a degraded form that became less degraded over eight steps, until the word became completely clear. Each step was presented after 1500ms. Based on the settings available on the PsyScope programme, the degrading began at 0.99 then progressed to 0.985, 0.975, 0.965, 0.95, 0.9, 0.8 and finally 0 (see Figure 10). The next word began after a 3000ms break. The child was requested to guess the word as soon as they thought they might know the answer, and not to worry about making mistakes. The task presented the 10 target words, as well as 5 additional words that had been learnt in previous sessions, presented in random order.

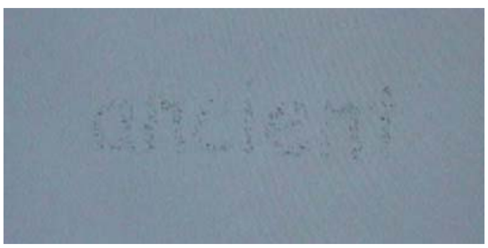
Figure 10: Degraded Images programme

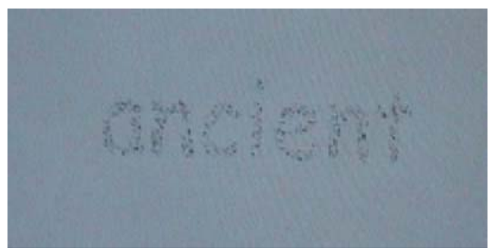
1. 

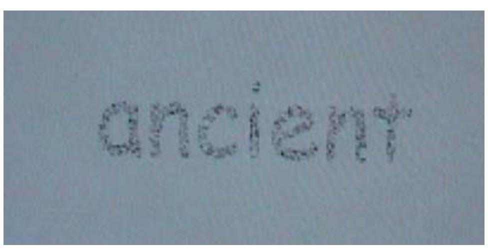
2. 

3. 

4. 

5. 

6. 

7. 

8. 

This procedure was followed for each of the ten training sessions. Following the completion of the ten sessions of the Whole-word Training Programme each child was readministered the Alternative Wordlists and was retested on the 100 target words they were trained on. Their responses to both these tests were recorded.

Results

Results from the trained words in the Whole-word Training Programme are presented in Table 13. All post-training scores were at, or near, ceiling, thereby clearly indicating that all children, both surface and phonological dyslexics, learnt their targetted regular and irregular words. A three-way mixed between-within subjects analysis of variance (ANOVA) was conducted to explore the impact of Testing Phase (pre- or post-completion of the Whole-word Training Programme), Subtype (phonological or surface dyslexic) and Wordtype (regular or irregular word) on reading accuracy for the target words. There was a statistically significant main effect of Testing Phase [$F(1, 8)=185.44$, $p<0.001$], with a very large effect size (eta squared=0.96). The mean scores indicate highly significant score improvements following completion of the Training Programme. The main effect for Wordtype also reached statistical significance [$F(1, 8)=19.51$, $p<0.01$], with a large effect size (eta squared=0.71). The scores presented in Table 13 suggest that this is due to the base rates for the regular words being higher than for the irregular words, due to attempts to match the wordsets in frequency as closely as possible. The interaction between Wordtype and Subtype reached statistical significance [$F(1, 8)=5.37$, $p<0.05$], suggesting the surface dyslexics attained significantly lower irregular word scores than the phonological dyslexics. The interaction between Testing Phase and Wordtype is also significant [$F(1, 8)=27.57$, $p<0.01$], suggesting the irregular word scores improved significantly more than the regular words following intervention, however this may be a result of the lower base rates attained for the irregular words. The three-way intervention was significant [$F(1, 8)=9.69$, $p<0.05$], further suggesting the surface dyslexics significantly improved their irregular word reading scores following intervention, more so than the phonological dyslexics. The main effect for Subtype did not near significance [F(1, 8)=0.00, $p=1.00$], nor did the interaction between Testing Phase and Subtype [$F(1, 8)=0.11$, $p=0.75$].

Table 13 – see end

Reading times were measured for trained words, read correctly both before and after training, and are presented in Table 13. These times improved following training, with both surface and phonological dyslexics almost halving their time taken to read the targetted words. A three-way mixed between-within subjects ANOVA was conducted to investigate the impact of Testing Phase, Subtype and Wordtype (regular or irregular) on Reading Times for the trained words. Results confirmed the improvement as significant, with the main effect of Testing Phase highly significant [$F(1, 8)=53.41$, $p<0.001$], with a large effect size (eta squared=0.87). The main effect for Wordtype was also significant [$F(1, 8)=15.90$, $p<0.01$], with a large effect size (eta squared=0.67), indicating the reaction times for the irregular words were significantly longer than the times for the regular words. The main effect for Subtype was not significant [$F(1, 8)=1.06$, $p=0.33$]. The interaction between Testing Phase and Wordtype is significant [$F(1, 8)=5.49$, $p<0.05$], suggesting that the reaction times for the irregular words improved significantly more than the reaction times for the regular words following the training programme. The interaction between Testing Phase and Subtype is not significant [$F(1, 8)=0.18$, $p=0.68$], nor is the interaction between Wordtype and Subtype [$F(1, 8)=3.77$, $p=0.09$] nor the three-way interaction [$F(1, 8)=1.37$, $p=0.28$].

Whole-word training programme generalisation results

The scores attained for the Alternative Wordlists are presented in Table 14. Unlike the Phonological Training Programme, no clear generalisation was observed from the Whole-word Training Programme to irregular word reading. The irregular word reading numerical scores generally improved slightly (on average, 3 points) following completion of the Whole-word Training Programme, but for most individuals, not substantially. This lack of substantial generalisation was confirmed by the results of a three-way ANOVA with the independent variables of Testing Phase (pre- or post-completion of the Training Programme), Subtype (phonological or surface dyslexic) and Wordtype (regular, irregular or nonword). There were statistically significant main effects for Testing Phase [$\underline{F}(1, 8)=17.96$, $\underline{p}<0.01$], Subtype [$\underline{F}(1, 8)=12.16$, $\underline{p}<0.01$] and Wordtype [$\underline{F}(2, 8)=17.75$, $\underline{p}<0.01$], all with large effect sizes (eta squared=0.69, 0.60 and 0.69, respectively). The data indicates that, overall, scores on the Alternative Wordlists improved significantly following completion of the Whole-word Training Programme, the surface dyslexics attained significantly higher scores than the phonological dyslexics, and that scores on the three wordtypes differed significantly. The interaction between Testing Phase and Wordtype was statistically significant [$\underline{F}(2, 8)=7.50$, $\underline{p}<0.05$], with a large effect size (eta squared=0.48), indicating the scores attained on the wordlists made significantly different improvements following completion of the training programme. The data presented in Table 14 suggests that, as with the Coltheart and Leahy wordlists in the Phonological Training Programme, the nonword scores improved significantly more than the regular and irregular scores. Some of the phonological dyslexics attained notable improvements on their nonword scores, for example, WC improved her nonword reading from 8 to 15 correct, GM from 12 to 20, PJ from 14 to 20 and LJ from 12 to 17 correct following completion of the Whole-word Training Programme. The interaction between Testing Phase and Subtype was not significant [F(1, 8)=1.85, p=0.21], nor was the three-way interaction between Testing Phase, Sutbype and Wordtype [F(2, 8)=0.30, p=0.60]. The interaction between Wordtype and Subtype neared, but did not reach significance [F(2, 8)=5.06, p=0.06].

Table 14 – see end

Table 15 presents the mean reading times attained by each individual for the Alternative Wordlists, before and after completing the Whole-word Training Programme. The times presented are only for the words that were read correctly both before and after the completion of the Whole-word Training Programme. Due to reading times not being produced for ST due to technical difficulties, and MT not correctly reading any nonword both pre- and post-programme, the sample size was reduced to 8, with data from only two surface dyslexics. Overall, both groups read the regular word, irregular word and nonword wordlists more quickly following completion of the Whole-word Training Programme. However, a three-way mixed within-between subjects ANOVA, with the independent variables of Testing Phase, Wordtype and Subtype, found that Testing Phase did not have a significant main effect [F(1, 6)=1.28, p=0.30], indicating that overall, reading times did not significantly change following completion of the Whole-word Training Programme. The main effect for Wordtype was significant [F(2, 6)=8.69, p<0.05],] with a large effect size (eta squared=0.59). The data indicates that, as with the Coltheart and Leahy Wordlists in the Phonological Training Programme, the nonwords had significantly longer reaction times than the regular and irregular words. The main effect for Subtype did not reach significance [F(1, 6)=0.53, p=0.50], nor did the interactions between Testing Phase and Wordtype [F(2, 6)=0.00, p=1.00], Testing Phase and Subtype [F(1, 6)=0.12, p=0.74], Wordtype and Subtype [$F(2, 6)=0.40$, $p=0.55$] nor the three-way interaction [$F(2, 6)=0.91$, $p=0.38$].

Table 15 – see end

Experiment 1 - Individual Results

Due to the variability between individual cases with developmental dyslexia, and the resulting impact this has on 'glossing-over' the results attained from group studies (Broom & Doctor, 1995b; Caramazza & McCloskey, 1988; Seymour, 1990), individual case studies from the current research will now be presented. The results of two of the children, PS, a surface dyslexic and MT, a phonological dyslexic, will be examined in greater depth to facilitate further comparison of the two dyslexia subtypes and their responsiveness to the two training programmes. Aspects of the data already presented will be highlighted here; the pre-tests will be discussed to identify any differences between the two individuals, then the training programme results will be compared and contrasted in terms of the effectiveness of the two training programmes for the two subtypes of dyslexia; surface and phonological. As stated earlier, the results for PS and MT have been presented in italics throughout the results tables.

The two case-studies reported here, PS and MT, were selected for detailed examination as they can be considered 'pure' cases of developmental dyslexia, they both exhibited comparable IQ levels (below average Verbal IQ and above average Performance IQ), and they showed a clear weakness in reading irregular words or nonwords. PS showed a very strong nonword reading ability, achieving 26 out of 30 nonwords correct on his initial reading of the Coltheart and Leahy (1996) wordlists, but had difficulty reading irregular words with his score placing him in the Band B category for irregular words. PS commonly made regularisation errors when reading irregular words, sounding out the word according to standard grapheme-to-phoneme rules. This pattern; of poor irregular word reading and regular (or above-regular for PS) nonword reading is consistent with developmental surface dyslexia. In comparison, MT showed an extreme weakness reading nonwords, initially reading only one out of thirty nonwords correctly. MT commonly made lexicalisation errors when reading the nonwords, reading them as similarly-shaped words. MT also had a significant impairment reading regular words. However his irregular word reading was much closer to normal, only just within the Band B (borderline) category. This pattern; of poor nonword reading and regular (or near-regular for MT) irregular word reading is consistent with developmental phonological dyslexia.

Method

Participants - Background Information.

PS was aged 12 years 10 months at the beginning of the current study. He is of Samoan ethnicity and has grown up in New Zealand in an environment of relatively low socio-economic status, however his home environment is stable. PS's parents primarily speak Samoan language at home, however both parents are also fluent in English, and the children predominantly speak English to each other. PS often spends his afternoons in the public library, doing homework and playing on the computers with some school friends.

MT was also aged 12 years 10 months at the beginning of the current study. He presented with poor phonological skills resulting in difficulty reading regular words, and great difficulty reading nonwords. In contrast, his reading level for irregular words was almost normal for his age (MT read 18/30 irregular words correctly; 19/30 is an age-matched 'normal' score). MT is of NZ European descent, having grown up in New Zealand. His father is of Dutch origin, however the family solely speaks English at home.

MT has an older sister, whom his mother says had also had great difficulty with phonological skills in earlier school years. According to MT's mother's reports, MT's primary school had focussed exclusively on whole-word reading. When MT initially began the Phonological Training Programme, his sounding-out skills were extremely poor, with MT having no clear concept of the sounds of letters.

Pre-testing Results

Following the initial background testing, PS was found to have a WISC-III Full Scale IQ of 93, with his Verbal IQ score of 80 significantly lower than his Performance IQ of 111. MT was found to have a Full Scale IQ of 89, with his Verbal IQ score of 76 also significantly lower than his Performance IQ of 106. Table 16 presents PS's and MT's subtest scores from the WISC-III. It is notable that all Verbal subtest scores are below average for both PS and MT, with MT's Information, Comprehension and Digit Span subtests very low. In comparison, the Performance subtest scores are much higher, with all of PS's, and the majority of MT's at, or above average.

Table 16.
PS's and MT's subtest scores for the WISC-III.

Verbal tests			Performance tests		
	PS	MT		PS	MT
Information	5	3	Picture Completion	11	11
Similarities	8	7	Coding	10	8
Arithmetic	9	7	Picture Arrangement	10	12
Vocabulary	4	7	Block Design	16	11
Comprehension	6	5	Object Assembly	11	12
Digit Span	8	5	Symbol Search	12	7

Both PS's and MT's reading age scores were clearly lower than their chronological age (12.10 years) for both the Neale Analysis and the Burt Word Reading test. On the Neale Analysis (Form 2) PS's reading age for accuracy was 8.05 years, for comprehension his reading age was 7.50 years, and for rate PS was placed at the reading level of 8.08 years. MT's accuracy reading age was 7.10 years, his comprehension reading age was 8.03 years, and his reading age for rate was 10.02 years. On the Burt Reading Test, PS's reading age was placed at 9.08-10.02 years, and MT's reading age was scored considerably lower, at 8.06-9.00 years.

On his initial reading of Coltheart and Leahy's (1996) wordlists, PS read 18/30 of the irregular words correctly, placing him in Band B (borderline performance) for irregular word reading. In clear comparison, PS read 27/30 of the nonwords correctly; well above the minimum normal score of 22/30. For the regular words, PS read 26 of the 30 correctly, placing him just in Band B for his age group; with 1 more regular word read correctly, he would have been placed in the Normal category. The dissociation between PS's superior ability in reading nonwords and his difficulties reading irregular words identified him as a clear case of developmental surface dyslexia. He commonly made regularisation errors when reading irregular words, for example, on the Coltheart and Leahy (1996) irregular wordlist, PS read the word 'break' as "breek", and for 'lose' he produced "loose". When reading irregular words PS was commonly surprised when given the correct pronunciation of the word – "oh, I get it, I can't believe I didn't know that!"

In contrast, on MT's initial reading of Coltheart and Leahy's (1996) wordlists, MT read 20 of the 30 regular words correctly, placing him in Band A which indicates a definite reading deficit for regular words. For the irregular words MT read 18 of the 30 correctly, placing him in Band B (the borderline category) for irregular words. When reading the nonwords MT was only able to correctly read 1 out of 30, which was a very low Band A score. This clearly indicated a significant reading deficit for nonwords, which, combined with his reading deficit for regular words, indicates MT's poor phonological processing awareness. When reading nonwords, MT commonly made lexicalisation errors, giving a regular word which was similar in word shape, or a word that started or ended with the same letter-string, for example, reading 'bick' as "brick", 'crat' as "catch", 'grenty' as "gently". Paralexical errors were also occasionally made when reading both regular and irregular words, substituting other similar-looking words, e.g. 'slime' was read as "smile", 'brooch' as "branch". MT's deficit in regular word and nonword reading, combined with his (near) normal irregular word reading clearly identifies him as a case of developmental phonological dyslexia.

PS's and MT's full results for each of the background tests were presented earlier in Tables 4 and 5 (noted by italics); only the tests of note will be presented here. For the Kaufman Gestalt subtest both PS and MT attained normed scores of 9, therefore below normal. On the Bead Memory subtest of the Stanford-Binet, PS attained a score of 51, which was one of the lower scores attained by the participants in the current study, while MT attained a score of 60, which was the highest score. The other point of note within the Visual tests was the notable increase in time taken for PS to identify the BORB overlapping letters or pictures compared to the non-overlapped – an increase of 0.10s and 0.32 s for each item, whereas MT made only a slight increase of 0.04s and 0.05s for each item.

On the visual-verbal and verbal skills pre-tests, MT attained average scores across the Castles and Coltheart Homophone tests, while PS attained the lowest score (21) of the participants when the target choice was an irregular word – indicating PS was more likely to incorrectly select a regularly spelt homophone or a nonword pseudohomophone than the correct irregular word. In comparison, PS scored the top score (9) on the ITPA Sound Decoding subtest, indicating good nonword reading (as would be expected given his previous scores on the nonword wordlists), while MT attained the lowest score (3). Further disparity was evident with PS attaining the top scores for the ITPA Sound Spelling (11) and Sound Deletion (13) subtests, while MT attained much lower scores - Sound Spelling (4) and Sound Deletion (6).

Overall Training

Comparison of Training Programmes for PS and MT

PS's and MT's results on the Coltheart and Leahy (1996) wordlists and the Alternative wordlists were analysed using simultaneous logistic regression analyses, incorporating testing phase as a repeated measure and fitted using Generalised Estimating Equations (GEE). Due to PS achieving ceiling with both the regular words and the nonwords in both the Coltheart and Leahy wordlists and the Alternative wordlists, and MT attaining very high scores with the regular words, it was not possible to run analyses on the children's complete data as the data could not be fit. Instead, analyses were run solely on PS's reading of the irregular words, and MT's reading of the irregular and nonwords, for both Coltheart and Leahy's (1996) wordlists and the Alternative Wordlists.

Chi-square analyses (for Type 3 GEE analysis) assessing PS's improvement in irregular word scores on the Coltheart and Leahy and Alternative wordlists after completing each remediation programme found there were no significant improvements, [$\chi^2(1)=2.60$, $p=0.11$]. There was also no significant difference in PS's irregular word scores between the two remediation programmes, [$\chi^2(1)=2.33$, $p=0.13$]. There was no significant interaction between Testing Phase and Programme Type [$\chi^2(1)=1.02$, $p=0.31$], indicating that any changes in PS's irregular word reading were not significantly different according to the training programme. This lack of significant findings for PS is in concordance with the group findings that the Whole-word Training Programme, although successful at improving the reading of the trained irregular words, did not result in generalisation to other irregular words. The slight improvement observed in irregular word reading suggests that it may be worth further examining generalisation in subsequent studies.

In comparison, chi-square analyses (for Type 3 GEE analysis) assessing MT's regular and nonword scores on the Coltheart and Leahy and Alternative Wordlists revealed a significant main effect for Testing Phase [$\chi^2(1)=5.30$, $p<0.05$], indicating that both wordtypes improved following both training programmes. Analysis revealed a highly significant main effect for Wordtype [$\chi^2(1)=60.04$, $p<0.001$], indicating MT attained significantly higher scores on the irregular words than on the nonwords. There was no significant main effect for Programme Type [$\chi^2(1)=0.18$, $p=0.67$]. Overall, there was no significant interaction between Programme Type (Whole-word or Phonological) and Testing Phase for MT's scores on irregular words and nonwords [$\chi2(1)=1.39$, $p=0.24$], indicating there was no significant difference in MT's improvements on the irregular word and nonword scores between training programmes. The three-way interaction between Testing Phase, Programme Type and Wordtype on MT's scores for irregular words and nonwords was highly significant [$\chi^2(3)=12.67$, $p<0.01$]. The data suggests that, compared to irregular words, MT showed a significantly greater improvement reading the nonwords after completion of the Phonological Training Programme.

Results of Reading Ability Tests

Following completion of both the training programmes, PS's and MT's general reading ability was re-assessed, with both the Neale Analysis and the Burt Word Reading test (see Table 8). PS's scores on the Neale Analysis had improved: on Accuracy from 8,7 years up to 13,3, Comprehension from 7,11 up to 9,10, and Rate from 9,9 up to 9,11 years. In comparison, MT's Neale Analysis scores showed only slight improvement and some decline: Accuracy improved from 8,1 up to 8,6 years, Comprehension increased from 8,5 up to 9,5 years, however Rate decreased from 10,5 to 7,11 years. PS's reading ability on the Burt Word Reading test also improved, from 11.05-11.11 pre-training, up to the ceiling score of greater than 13.03 years. Again MT's Burt score showed a slightly lesser improvement than PS's, from 8.06-9 pre-training, up to 9.11 to 10.05.

Table 8 – see end

Phonological Training Programme

The Phonological Training Programme was the initial programme administered to PS and the second programme for MT (his target programme). Each participant's ten target grapheme-to phoneme correspondences (GPCs) are listed in Table 17 in the order in which they were trained, and with the scores they attained pre- and post-remediation.

Table 17.

PS's and MT's target GPC scores, pre- and post-Phonological Training Programme.

PS			MT		
Target GPC	Pre-Phonl Prog	Post-Phonl Prog	Target GPC	Pre-Phonl Prog	Post-Phonl Prog
1. 'IE'	2/10	9/10	1. 'AU'	2/10	6/10
2. 'OO'	3/10	5/10	2. 'A_E'	3/10	8/10
3. 'OA'	5/10	6/10	3. 'U_E'	3/10	7/10
4. 'O_E'	7/10	10/10	4. 'PH'	3/10	8/10
5. 'U_E'	7/10	7/10	5. 'OA'	3/10	7/10
6. 'OW'	8/10	8/10	6. 'IE'	3/10	8/10
7. 'QU'	8/10	10/10	7. 'I_E'	4/10	7/10
8. 'A_E'	9/10	10/10	8. 'TH'	4/10	7/10
9. 'I_E'	9/10	10/10	9. 'O_E'	4/10	8/10
10. 'TH'	9/10	10/10	10. 'OO'	4/10	6/10
Total	67/100	85/100	Total	33/100	72/100
Overall Improvement		27%	Overall Improvement		118%

A paired t-test determined that PS's improvements on the target GPCs were significant, [$t(9)=2.79$, $p<0.05$], as were MT's target GPC improvements [$t(9)=12.40$, $p<0.01$]. Overall, on the GPC Selection test, PS's score improved from 166 up to 183 out of 200 following completion of the Phonological Training Programme. The improvements on the target GPCs accounts for this overall improvement, indicating no further generalisation to untrained GPCs. In comparison, MT's 56-point improvement on the GPC Selection test (from 100 up to 156) is not solely accounted for by the improvement on the target GPCs (an improvement of 39), thereby indicating further generalisation to untrained GPCs.

PS's scores on the Coltheart and Leahy (1996) Wordlists indicated some improvement on both the regular and nonwords (Table 11), however, both the regular and nonword lists were nearing ceiling pre-programme so little improvement was possible.

There was no evidence for improvement on PS's irregular word reading. MT exhibited numerical improvement on his nonword reading exclusively (Table 11). PS's reaction times for reading each of the wordlists improved following completion of the Phonological Training Programme, most notably for the irregular and nonwords (Table 12). A paired t-test conducted on this data indicated that these improvements in reaction time for irregular and nonwords were both significant: irregular words [$t(17)=2.28$, $p<0.05$] and nonwords [$t(26)=3.59$, $p<0.01$]. In comparison, the reaction time results for MT indicate that the Phonological Training Programme resulted in him slowing down his reading, presumably in order to sound out the words correctly (Table 12). Paired-sample t-tests were conducted on his regular and irregular word reaction times (not nonword due to there only being one item), indicating the slowing of his irregular word reading was significant [$t(21)=2.67$, $p<0.05$].

Tables 11 and 12 – see end

Following completion of the Phonological Training Programme, PS showed an improvement in reading age accuracy from 8.07 to 9.11 on the Neale Analysis, while MT showed a smaller improvement from 8.02 to 8.06.

Whole-word Training Programme

The Whole-word Training Programme was the initial programme administered to MT and the second programme for PS (his target programme). In his initial reading of the target regular and irregular wordlists, PS read a very high number of the regular words correctly, resulting in his target regular wordlist comprising the final 50 words of the list.

The Degraded Images exercise, which comprised part of the whole-word training, provided some information about the children's visual word analysis skills. For PS, the mean number of beeps that had passed prior to him reading the words correctly was 3.36 (SD=1.05). The irregular words were read at a slightly quicker pace than regular words; Regular words, M=3.44 beeps, SD=1.10, Irregular words, M=3.28 beeps, SD=1.01. An independent t-test revealed this difference to not be significant [$t(147)=0.95$, $p=0.34$]. Towards the end of Whole-word Training Programme, PS made a few errors within the Degraded Images exercise, incorrectly reading the word as a similarly-shaped word, for example PS read 'thrifty' as "rhyme", 'comb' as "chorus", 'diary' as "daisy". PS quickly corrected himself and read the word correctly as it became clearer. Such errors indicate PS was beginning to place a greater reliance on whole-word processing, rather than exclusively relying on sounding-out each word.

For MT, the mean number of beeps that passed prior to him reading the words correctly on the Degraded Images section was 2.66 (SD=0.98). This approximates 2.49 seconds, which is notably quicker than PS, with each word degraded to a level of 0.985 at that point. MT read the regular words at a slightly quicker pace than the irregular words; Regular words, M=2.61 beeps, SD=0.96, Irregular words, M=2.71 beeps, SD=1.00, however an independent t-test revealed this difference to not be significant [$t(143)=0.62$, $p=0.53$]. During the exercises, as with PS, MT also made errors where he guessed a similar-shaped word after very little time (generally 1 or 2 beeps), indicating MT's focus on the wordshape. For example MT initially guessed "echo" for 'comb', "shelf" for 'shaft', "schedule" for 'scheme'. He quickly corrected each error as the word became clearer.

PS's and MT's scores for their targetted regular and irregular words pre- and post-remediation are presented in Table 13. Following completion of the Whole-word Training Programme, both children had improved their reading of the targetted words up to, or near ceiling. Chi-square analyses revealed highly significant improvements in PS's reading of the targetted words, for the target irregular words ($\chi2=52.55$, $p<0.001$), for the targetted regular words ($\chi2=26.58$, $p<0.001$), and overall ($\chi2=76.14$, $p<0.001$). Similarly, chi-square analyses on MT's data revealed highly significant improvements in MT's reading of the targetted words, for the target irregular words ($\chi2=44.93$, $p<0.001$), for the targetted regular words ($\chi2=35.14$, $p<0.001$), and overall ($\chi2=79.72$, $p<0.001$). Reaction time data for the trained words is also presented in Table 13. PS significantly improved his reading times for both the regular words [$t(28)=3.11$, $p<0.01$] and the irregular words [$F(13)=2.27$, $p<0.05$]. MT also improved his times for both wordtypes numerically, however only the regular word improvement was significant: [$t(23)=2.65$, $p<0.05$], with the irregular words nearing, but not reaching significance [$t(18)=1.84$, $p=0.08$].

Table 13 – see end

PS's and MT's scores and reaction times for the Alternative Wordlists are presented in Table 14 and 15. As with the Coltheart & Leahy (1996) wordlists, PS achieved ceiling for the regular words and nonwords in the post-test. There was some suggestion of PS improving on the irregular words following training. MT's scores on the regular words, irregular words and nonwords all showed little or no improvement following completion of the Whole-word Training Programme. Reaction time data is also presented for words read correctly both before and after training. PS improved his reaction times numerically for reading regular, irregular and nonwords, however this was not significant for any of the wordlists: regular words [$t(29)=1.22$, $p=0.23$], irregular words [$t(21)=1.18$, $p=0.25$], nonwords [$t(27)=0.95$, $p=0.35$]. MT's data does not include reaction times for the nonwords, as no nonwords were correctly read both before and after completion of the Whole-word Training Programme. For the regular and irregular words, reaction times remained very similar following training, confirmed by a lack of significance: regular words [$t(23)=0.28$, $p=0.78$], irregular words [$t(20)=0.04$, $p=0.97$].

Tables 14 and 15 – see end

Discussion of Experiment 1 Training Programmes

Following completion of the two reading training programmes: the Phonological Training Programme and the Whole-word Training Programme, several key findings were made. Firstly, both training programmes were effective in significantly improving all children's reading of the trained words. In the Phonological Training Programme, reading of words and nonwords containing the targetted GPCs significantly improved following completion of the programme, while reading of items containing non-target GPCs did not show the same improvement. However, generalisation was observable for both phonological and surface dyslexics with significant improvements on the nonword wordlist following programme completion. On the Whole-word Training Programme, all children performed at, or near ceiling following completion of the programme, with highly significant improvements. No significant generalisation was found for reading of untrained irregular words. In a comparison of the scores attained on the Coltheart and Leahy and Alternative wordlists administered pre- and post-completion of the two training programmes, a significant interaction was found between Programme Type, Testing Phase and Wordtype, indicating that the participants' scores on specific wordtypes significantly improved following completion of a specific programme. It can be seen in the data that the nonword scores for both dyslexia subtypes improved significantly following completion of the Phonological Training Programme, thereby indicating the Phonological Training Programme resulted in significantly greater generalisation than the Whole-word Training Programme.

A few points warrant further discussion. The first of these concerns the role of IQ in participants' performance on both the background tests and the treatment programmes. Two of the surface dyslexics in Experiment 1, MJ and ST, were found to have low IQs, which may have impacted on their scores. On many of the Visual tests in the Background Testing, both individuals attained notably lower scores than the other participants. These findings suggested the current research might support previous research that has correlated surface dyslexia with visual difficulties (Boder, 1971; Bayliss & Livesey, 1985; Goulandris & Snowling, 1991; Samuelsson et al., 2000). However, the other surface dyslexic in the current study, PS, whose IQ was at a notably higher level, generally attained average scores on the Visual tests (except for the Kaufman Gestalt subtest), suggesting MJ's and ST's lower scores may be related to their lower IQs. On the training programmes, although the participation of children with lower IQ was unplanned, MJ's and ST's responsiveness supported their inclusion. Their low scores for overall intelligence did not impact on their ability to learn, and, without any difficulties experienced, both training programmes were effective for them. This finding is consistent with a longitudinal study conducted by Hatcher and Hulme (1999) that found that IQ is not a reliable predictor of children's responsiveness to reading remediation. Hatcher and Hulme concluded that this finding suggests that rather than the current requirement that children exhibit 'normal' IQ in order to be selected for reading treatment, selection of children for reading programmes should be solely based on their reading disability.

The second point involves the effectiveness of the two training programmes, both in training specific words, and generalisation. The Phonological Training Programme improved all children's ability to read words containing their targetted GPCs. The phonological dyslexics showed greater numerical improvement than the developmental surface dyslexics, with the interaction between dyslexia Subtype and Testing Phase nearing, but not reaching significance. This difference in score improvements may have resulted from the lower base score attained by the phonological dyslexics prior to the training programme. Indeed, this result is perhaps not surprising, given that the training programme was focussed on addressing the hypothesised reading difficulty of the phonological dyslexics; grapheme-phoneme transcoding. The developmental surface dyslexics were already capable of this skill.

Some generalisation was observable with the Phonological Training Programme in the nonword scores from the Coltheart and Leahy (1996) wordlists. The majority of the children (9 out of 10) improved their nonword reading scores following completion of the Phonological Training Programme, with nonword scores improving more than regular and irregular words. The interaction between Testing Phase and Wordtype neared, but did not reach significance. However, in the individual case-study analysis, a significant interaction between Testing Phase, Wordtype and Programme Type was found for the phonological dyslexic MT, suggesting he significantly improved his reading of nonwords after completion of the Phonological Training Programme. This finding, in part, supports the hypothesis that, as developmental phonological dyslexics have most difficulty with nonwords, rather than regular or irregular words, their GPC awareness and 'sounding-out' ability will show greater improvement after completion of the Phonological Training Programme, rather than the Whole-word Training Programme. The observed generalisation of the skills learnt in the Phonological Training Programme is consistent with other phonologically-based reading training programmes (Brunsdon et al., 2002a ; Lovett et al., 1994; O'Shaughnessy & Swanson, 2000; Seymour & Bunce, 1994; Williams, 1980, 1981).

The other field where generalisation was potentially observable in the Phonological Training Programme was in the words and nonwords containing untrained GPCs in the post-test of the GPC Selection test. Although three of the developmental phonological dyslexics showed numerical improvement on their untrained GPCs, there was no significant overall improvement on Nontarget GPCs. This finding is not consistent with the study being replicated; Broom and Doctor's (1995b) programme, which found that, although their case study, SP, improved his reading of regular words containing the trained GPCs significantly more than words containing untrained GPCs, the training did result in significant improvement on untrained GPCs.

Analysis of the reaction times for the Coltheart and Leahy regular, irregular and nonword lists potentially provides some insight into the nature of the underlying cognitive impairment of the participants. Following completion of the Phonological Training Programme, overall reaction times for the wordlists were found to increase for the phonological dyslexics but decreased for the surface dyslexics. Analysis of the individual case studies found that PS (the surface dyslexic) significantly sped up his reaction times for reading the irregular words and the nonwords following programme completion. This 'speeding-up' may have resulted from the Phonological Training Programme allowing PS to practice sounding-out and further these skills for the nonwords, however, his improved reaction times for the irregular words are unexpected. In comparison, MT (the phonological dyslexic) slowed his reading of the regular, irregular and nonword wordlists following completion of the Phonological Training Programme, presumably to enable him to focus on sounding out each word. This 'slowing-down' was significant for the irregular words, and neared significance for the regular words. Although there was a clear increase in MT's reaction time on the nonword list, further analyses could not be conducted due there being only one nonword read correctly both before and after completion of the training programme. Although the resulting 'slowing down' of reading looks like a drawback, employment of the Nonlexical route is essential for reading nonwords and unfamiliar regular words, and, in the current research, appears to have aided MT in improving his nonword score. Training in the employment of the Nonlexical route is also valuable for phonological dyslexics as it has the potential to further enable them to make distinctions between similarly-shaped words, reducing the frequency of paralexical errors. The concept that the Phonological Training Programme may have resulted in MT developing his use of the Nonlexical route is further supported by MT's specific significant slowing of his irregular word reading. This may, in part, be due to the application of GPCs being inappropriate for irregular words so would have then required MT to further analyse the word in order to read it correctly. In comparison, the surface dyslexics already relied on sounding out each word, rather than focussing on the whole word, suggesting that the additional training in GPC awareness assisted them in speeding up their reading. Reliance on the Nonlexical route for reading (focussed on sounding out words) has been found to result in a generally slowed response pattern, compared to using the Lexical route (whole-word reading) (Seymour, 1986, 1987a). The significant increase in MT's reaction times supports the idea that the Phonological Training Programme effectively trained the use of the Nonlexical route for reading.

The Whole-word Training Programme was highly effective in improving the surface dyslexics' and the phonological dyslexics' reading of both the trained regular and irregular words; the final scores for all being at, or near ceiling. The times taken to read the trained words correctly also improved substantially, with no clear difference between the phonological and surface dyslexics. The quicker reading times following completion of the Whole-word Training Programme may be attributable to either the whole-word (lexical) approach to reading being quicker than relying on a phonological 'sounding-out' process (non-lexical), or the familiarisation of the trained words. This finding suggests that the Whole-word Training Programme, given further time and extension, may have the potential to develop an individual's lexical focus. This would be particularly valuable for treatment of surface dyslexia.

Unlike the Phonological Training Programme, there was no observable generalisation to untrained irregular words following completion of the Whole-word Training Programme, for either the phonological or the surface dyslexics. This lack of generalisation is consistent with the results of Broom and Doctor's (1995a) original developmental surface dyslexia case study on which the current study is partially based. This lack of generalisation supports Weekes and Coltheart's (1996) suggestion that generalisation to untrained irregular words may be limited to acquired surface dyslexics, because it relies on premorbid knowledge of the words concerned. This belief was potentially countered by Brunsdon et al.'s (2002b) finding of observed generalisation in their case study of TJ, a developmental mixed dyslexic. However, it is important to note that, although a whole-word approach was being employed for training, TJ was being trained and tested using solely regular words, with no irregular. As a result, it is possible that TJ's phonological skills improved, resulting in his improved ability to read other untrained regular words. If this is the case, the current study's findings of lack of generalisation following a whole-word focussed training programme do not counter any previous research.

The lack of generalisation from the Whole-word Training Programme is perhaps not surprising, considering that it teaches irregular words, which are idiosyncratic by definition. Perhaps a longer training period would result in the child developing their reading skills to a point where they begin to rely more heavily on whole-word processing, as well as developing a larger visual word memory. This would enable the child to correctly read previously encountered irregular words and, overall, to read at a faster rate (Seymour, 1986). However, the ten 40-minute sessions of whole-word training given here may not have been enough to enable such general whole-word processing skills to be developed. Further research involving a longer-term treatment programme could investigate whether the skills taught in a whole-word programme can be generalised effectively.

Further examination of the results from the Alternative Wordlists indicated that, although no consistent improvement in irregular word reading was observed following completion of the Whole-word Training Programme, some of the phonological dyslexics' nonword scores improved, despite no phonological training. This finding supports previous research which has suggested the presence of an interplay between both lexical and nonlexical skills, and reading ability; that as children improve their nonlexical skills they also improve their general reading ability, and vice versa (Stuart & Coltheart, 1988; Brunsdon et al., 2002a).

In contrast to the Phonological Training Programme, the Whole-word Training Programme resulted in decreased overall reading times on untrained words for both surface dyslexics and phonological dyslexics. This could indicate an overall change in reading focus and ability; following the Whole-word Training Programme the children may have begun to employ the lexical route for reading; rather than focussing on each grapheme in the word and sounding it out, thereby developing a greater reliance on using the overall word shape to read a word, and speeding up their reading. However, case study analyses for PS (the surface dyslexic) and MT (the phonological dyslexic) revealed the changes were not significant.

A range of techniques was employed in the Whole-word Training Programme, aiming to train participants in the use of the lexical route for reading. One such technique was Degraded Images, where target regular and irregular words were presented in a degraded form that became less degraded over eight steps. Case-study analysis revealed a clear difference in reaction times for the surface dyslexic (PS) and the phonological dyslexic (MT), on the Degraded Images task, with the phonological dyslexic notably quicker. This difference in time taken to correctly identify the word may correspond to the dyslexia subtype; MT is skilled at whole-word reading so, according to cognitive neuropsychologists, would rely on the lexical route for reading, which has been found to be quicker than sounding-out words (Seymour, 1987a). In comparison, PS is not skilled at whole-word reading, as indicated by his poor irregular word reading, so would rely on the nonlexical route for reading, which may have resulted in his slower recognition of the degraded word. It was also noted that, during the degraded images task, PS made several errors, guessing the words before they were clear. The importance of this is that his errors were paralexias - words that were visually-similar to the actual word, for example guessing "daisy" for the word 'diary', thereby indicating some reliance on overall word-shape, rather than solely focussing on each grapheme and its corresponding phoneme.

Another technique used in the Whole-word Training Programme was the use of Visual Mnemonic flashcards to encourage the use of visual whole-word recognition. This approach was based on a number of effective case studies previously conducted with acquired and developmental surface dyslexics that have employed visual mnemonics (Behrmann, 1987; Brunsdon et al., 2002b; Coltheart & Byng, 1989; De Partz et al., 1992; Weekes & Coltheart, 1996). However, the most recent study employing a whole-word training programme (Brunsdon et al., 2002b) found that, compared to standard 'word-only' flashcards, the use of visual mnemonic flashcards did not actually increase the effectiveness of their training programme. Brunsdon et al.'s research suggests that rather than focussing on visual mnemonics, which require additional time to teach, treatment programmes for surface dyslexia could solely focus on the standard 'word-only' flashcard, thereby creating additional time to teach a greater number of words. This raises the possibility that our visual mnemonic flashcards may not have aided the learning of targetted words, and the words would have been equally effectively learned without the visual aids.

Multiple techniques were used concurrently in the Whole-word Training Programme in Experiment 1, including degraded images, visual mnemonic flashcards, 'word-only' flashcards and cloze tasks, making it impossible to isolate the effects of each individual technique. Further research is required to investigate which of the training techniques are most effective, and which are surplus to learning. Such research would enable future whole-word training programmes to be as effective and efficient as possible, teaching the maximum number of words over the given time period. Furthermore, due to all participants reaching ceiling in Experiment 1, further research could extend the list of training words, to investigate the maximum number of training words possible. With a specific focus on solely irregular words, rather than also including regular words, the research could ensure children are required to employ a lexical reading approach. Also, it would be advantageous for future research to teach the same list of irregular words to each child, to remove some of the comparison difficulties encountered in Experiment 1, where each child received a differing set of trained words.

Overall, analysis of the generalisation effects for the two training programmes (through results of the Coltheart and Leahy wordlists and the Alternative Wordlists) indicates that both the training programmes resulted in significant improvements for both subtypes across the regular, irregular and nonword wordlists. Scores were significantly different for the three wordtypes, with the nonwords lowest, and the phonological dyslexics attained the lowest overall scores. A significant interaction between Testing Phase and Wordtype indicated that, following completion of both training programmes, the nonword scores for both subtypes increased more than the other wordtypes. Further findings related solely to the scores of the phonological dyslexics indicated that, as for the overall scores, the main effects and interaction of Testing Phase and Wordype were significant. Case-study analysis provided further comparison between the two subtypes, finding that the irregular word scores for PS (the surface dyslexic) showed no significant main effects or interactions for Testing Phase or Programme Type. In comparison, the regular word and nonword scores for MT (the phonological dyslexic) indicated significant main effects of both Testing Phase and Wordtype, with MT improving his scores following completion of both training programmes, and attaining lower scores for the nonwords than the regular words. The three-way interaction between Testing Phase, Programme Type and Wordtype was also significant, suggesting MT improved his reading score of the untrained nonwords significantly more following completion of the Phonological Training Programme. This provides some support for the hypothesis that the phonological dyslexics would respond better to the Phonological Training Programme. Overall, a limitation of Experiment 1 is the small size of the tests employed to investigate generalisation. The Coltheart and Leahy (1996) and the Alternative wordlists comprised merely 30 words within each of the wordlists, resulting in low power in the generalisation data and little range for further examination. Future research would require lists containing a greater number of matched words, to provide greater power to the statistics.

Although all children learnt the targetted words and GPCs in both programmes, the scores obtained on the Neale Analysis and the Burt Word Reading Test did not provide evidence for a consistent improvement in general reading skills across participants. Although some children showed a noticeable improvement (for example, PS improved on the Neale Form 2 from 8.7 years accuracy up to 9.10 years accuracy, and on the Burt from 11.05 years to higher than the ceiling limit of 13.03 years after completing both the programmes), the results were not consistent and there was discrepancy between the two reading tests, whereby some children showed significant improvement on the Neale but showed a much lesser or no improvement on the Burt.

A limitation of Experiment 1 was the low number of developmental surface dyslexics who were involved (n=3). As a result, statistical analyses involving this group were of low statistical power and their outcomes were consequently inconclusive. A further limitation on the results obtained from the developmental surface dyslexics is the low IQ of MJ and ST, which results in their results being incomparable with other studies involving developmental surface dyslexics as the individuals in such studies were required to have ‘normal’ IQ prior to receiving training. As mentioned above, the low IQ of MJ and ST may not have affected their responsiveness to the training programmes however we are unable to investigate this fully.

Another potential methodological limitation was the inherent difficulty involved with working with a group of eleven- to thirteen-year-old children both during school-time and after school-hours. For the school-time sessions the researcher attempted to ensure all children were removed from class during a language-related lesson to ensure they did not fall behind in another subject or miss out on a class that they particularly enjoyed, such as sports or art. However this was not always possible, which was observed to impact on the child’s motivation during a session. If the child had limited motivation or poor attitude during a post-testing session, this could skew their results to a lower level than they were capable of, suggesting that the child had not responded to the training programme. Some of the children had a large number of days where they did not attend school, primarily due to illness, religious festivals or family matters. This resulted in catch-up sessions being required, so that, generally for the final training programme, extra sessions were conducted or, if there were no other options, some sessions were doubled-up to ensure the child completed the full programme. This resulted in the children receiving the programme in different formats, with their second programme conducted over a shorter timeframe, which may have limited the child's development of the trained skills. Although the order of training programmes was balanced across dyslexia subtypes, with half receiving the Phonological Training Programme first and half receiving the Whole-word Training Programme, this difficulty may have impacted on the children's responsiveness to the training programmes.

Chapter 4: Experiment 2

Experiment 2 was developed to 1) address a number of the difficulties identified with Experiment 1, and 2) to further investigate the effectiveness of the training programmes for each subtype. As with Experiment 1, the same procedure was generally followed, with four major changes: First, in order to address the lack of power in Experiment 1's generalisation data, the Wordlists used to examine generalisation were expanded to twice the original length (to 60 words each wordtype). Also, additional generalisation information was attained through word and nonword spelling tests. Second, full IQ was assessed prior to selection of participants, to ensure participants' IQ was within the 'normal' range. Third, to further enable comparison to be made between the dyslexia subtypes, two single case studies were focussed on, rather than a group study. These case-studies were well-matched in terms of age, gender and IQ, enabling their performance on the background testing and training programmes to be examined in greater detail. Furthermore, the decision to focus on two prototypical examples enabled the selection of cases that best exemplified the extremes of the phonological-surface dyslexia continuum, that is, cases that, according to the dual-route model, exhibited a clear dissociation between their nonword and irregular word reading abilities. Fourth, in the Whole-word Training Programme, two of the primary treatment techniques were examined separately to enable comparison of effectiveness. The treatment techniques selected for further comparison were Visual Mnemonics and Degraded Images. The Visual Mnemonics is the technique most commonly employed specifically to address irregular word reading deficits (Broom and Doctor, 1995a; Brunsdon et al., 2002b; Coltheart & Byng, 1989; De Partz et al., 1992; Weekes & Coltheart, 1996;). The Degraded Images technique was developed specifically for this research, and therefore warrants some further investigation. A number of other more minor changes were made in the Whole-word Training Programme: unlike Experiment 1, the training set used in Experiment 2 consisted entirely of irregular words. This set of irregular words was expanded to 200 words, all of which were trained to both participants.

As with Experiment 1, Experiment 2 comprised three sections: Screening and Selection, Background Testing and the Training Programmes. The screening and selection of participants for Experiment 2 followed a two-step process, with the aim of identifying one prototype case of phonological dyslexia and one prototype surface dyslexia case to participate in the training programmes. Initially a large group of reading-disabled children (as identified by their classroom teachers) were administered a test battery to assess their general reading ability, give an indication of their intelligence, and examine their reading of regular, irregular and nonwords. Following this, a smaller group of participants were selected according to them demonstrating a clear dissociation between their nonword and irregular word reading ability, as indicated by their scores on the Coltheart and Leahy (1996) wordlists. Then further assessment was conducted with the smaller group to determine their full IQ. Two children who clearly met the reading criteria for phonological or surface dyslexia, attained normal or near-normal IQs, and were well-matched to one another in terms of gender, age and IQ were selected.

As for Experiment 1, Background Testing involved a full assessment of the reading and reading-related abilities of the selected participants. Tests were as for Experiment 1, with the following exceptions. First, the BORB Minimal Features and the three PALPA Verbal subtests were omitted because all children achieved ceiling or near ceiling scores on these tests in Experiment 1. Second, the ITPA Sound Decoding and Sight Decoding subtests were omitted as the information they provided was thoroughly examined in the lists of regular, irregular and nonwords used to examine generalisation. Throughout the

Background Testing and Training Programmes sections, as with Experiment 1, the results for the surface dyslexic (NS) are presented on the left-hand side, and noted 'SD' (surface dyslexic), and the results for the phonological dyslexic (WB) are presented on the right-hand side, noted 'PD' (phonological dyslexic).

After completing the general pretesting, the two participants in Experiment 2 began the two reading training programmes: 1) the Phonological Training Programme and 2) the Whole-word Training Programme. These were based on the training programmes in Experiment 1, with some variations, as outlined below. The Whole-word Training Programme focussed exclusively on training irregular words, with both children trained on the same 200 words, in the same order, to enhance comparison between results. All words received training using standard flashcards and cloze tasks, then each word received one of two training techniques; either the child was presented with a Visual Mnemonic flashcard, or they completed a Degraded Images task. These two training techniques were alternated between sessions, with the trained words balanced in frequency between the two techniques. Unlike Experiment 1, trained words from previous sessions were not revised at the beginning of each new training session, to remove the potentially confounding effect of repetition on memory. For both training programmes, the Generalisation wordlists were extended from 30 words each list up to 60 words, to provide the generalisation results with greater power. The generalisation tests were administered before and after completion of the full training programme, so did not enable any analysis of specific effects of each of the training techniques in the Whole-word Training Programme. Both participants completed the Phonological Training Programme initially (WB's target programme), followed by the Whole-word Training Programme (NS's target programme).

Screening and Selection of Participants

Method

Participants.

As with Experiment 1, general pretesting was initially conducted to identify children fitting the key criteria for selection into the programmes. 49 students at School A were assessed, who had been identified by their teachers as meeting the following criteria; they were one year or more behind their chronological age in reading, were working at the age-appropriate maths level, and spoke English as their first language. The parents of all children who were tested were informed by the school. The resultant sample of 49 children comprised 21 boys and 28 girls ranging in age from 10 years 9 months to 12 years 11 months (mean age = 11 years 8 months). Data collection for Experiment 2 was conducted approximately one and a half years after Experiment 1, so none of the sample in Experiment 2 had participated in Experiment 1. From this initial sample, six children were selected to complete a full-IQ assessment.

Materials.

The initial test battery used for selection of participants was as for Experiment 1, with the exception that the Neale Analysis of Reading Ability – 3rd Edition (Neale, 1999) was not administered. The resulting test battery comprised the Burt Word Reading Test – New Zealand Revision (Gilmore et al., 1981), Coltheart and Leahy's (1996) wordlists and the Block Design subtest of the WISC-III (Wechsler, 1992). For Part 2 of the screening and selection, the full WISC-III was administered.

Procedure.

For both parts of the screening and selection procedure, all children were assessed individually in the school's meeting room, during school time. The procedure was as for Experiment 1, with the omission of the Neale Analysis.

Results

Raw and scaled scores were calculated for each child's scores on the three tests. Means and standard deviations of the scores for the 49 children in Part 1 are presented in Table 18.

Table 18 – see end

Following the pretesting of the group of 49 children, results again indicated a wide range of reading ability, with some children scoring above their chronological age. Overall, the mean reading age (as indicated by the Burt Word Reading Test) was approximately two years below the mean chronological age of the children. From the 49 children, twenty potential phonological dyslexics and 6 potential surface dyslexics were identified according to a specific weakness exhibited in either their nonword, or irregular word reading, respectively. Further requirements for selection into Part 2 of the procedure were as specified in Experiment 1; a) their reading age (as indicated by the Burt Word Reading Test) was at least eighteen months below their chronological age, b) their scaled score on the WISC-III Block Design subtest was 8 or above, and c) their score on Coltheart and Leahy's (1996) wordlists indicated placement within different Bands for irregular word and nonword reading.

The scores on the WISC-III attained by the six children selected for Part 2 of the Screening and Selection procedure are presented below in Table 19.

Table 19.

General information and IQ scores of the six selected participants in Part 2 of the Screening and Selection procedure of Experiment 2.

Child	Age	Sex	Burt age	Wordlists (/30)[1]			WISC-III		
				Reg	Irreg	Non	Full	Verb	Perf
CP	11.01	M	9.00-9.06	29 N	16 B	22 N	84	88	83
MJ	11.11	F	8.05-8.11	27 N	19 N	8 A	91	83	102
NS	10.11	M	6.09-7.03	23 B	9 A	18 N	100	90	112
TQ	12.06	M	7.07-8.01	22 A	17 B	9 A	74	100	85
TT	11.08	M	8.04-8.10	22 A	19 N	10 A	95	92	100
WB	10.10	M	8.01-8.07	19 A	18 N	3 A	92	83	103

From the above results two individuals were selected to participate in the training programmes: one surface dyslexic (NS) and one phonological dyslexic (WB). This selection was made on the basis of a combination of factors: 1) their scores on the Coltheart and Leahy (1996) wordlists indicated an extreme difference between irregular word and nonword reading, 2) their IQ scores: any child scoring below 85 on their full-scale IQ was excluded, and 3) how well-matched they were in terms of age and gender to other potential cases. The two children selected clearly met criteria 1) and 2), and were well-matched to each other, being of virtually the same age, and both male. Their general background information and pre-test scores are presented above in Table 19. Further background information regarding each of the two selected participants is presented below. One of the

[1] Note: Letters indicate reading band – A=Band A, indicates definite reading deficit, B=Band B, indicates borderline performance, N=Normal reading level for age group

boys, NS, met the criteria for ‘surface dyslexia’, as his reading of irregular words was clearly weaker than his reading of nonwords. This was vice versa for WB, whose nonword reading skills were weaker than his irregular word reading, thereby meeting the criteria for phonological dyslexia.

Two back-up cases also completed the programmes simultaneously, in case of withdrawal by a key participant. The back-up cases did not fit the criteria as well as the case-studies, due to low IQ (PS – surface dyslexia back-up) or not so well-matched to the other case study (TT – phonological dyslexia back-up). Data from the two back-up cases are presented in Appendix T. As with Experiment 1, prior to conducting the programme pretests, each of the four children and their parents completed consent forms (Appendices E and F).

Background information - NS.

NS was aged 10 years 11 months at the beginning of Experiment 2. He is of New Zealand Māori descent and has grown up in New Zealand with his mother and siblings. NS’s early schooling was conducted in partial-immersion Māori language schooling: kohanga reo for early childhood education, followed by primary schooling at a kura kaupapa. NS transferred to mainstream schooling one year prior to participating in the current research. Although NS received formal schooling in Māori language, his family and extended family primarily speak English at home, although they also all speak Māori at times. NS is completely fluent in English but has not progressed beyond the early stages of the Māori language. His mother currently works two jobs, and is very supportive of education as a means to achievement. NS frequently stays with members of his extended family while his mother is working. NS generally spends his afternoons either at home or at his mother’s office, watching television or playing on the computer.

Following the initial background testing, NS was found to have a WISC-III Full Scale IQ of 100, with his Verbal IQ score of 90 significantly lower than his Performance IQ of 112. Table 20 presents NS's subtest scores from the WISC-III. It is notable that NS attained very high scores in two of the Performance subtests; Picture Completion and Block Design.

Table 20.

NS's subtest scores for the WISC-III.

Verbal tests		Performance tests	
Verbal IQ	90	Performance IQ	112
Information	5	Picture Completion	14
Similarities	10	Coding	9
Arithmetic	10	Picture Arrangement	11
Vocabulary	8	Block Design	14
Comprehension	8	Object Assembly	11
Digit Span	8		

NS's reading age score on the Burt Word Reading test (6.09-7.03) was substantially lower than his chronological age (10.11 years). Overall, NS's reading presented as notably slow and hesitant, and he appeared to be focussing on sounding each word out.

On his initial reading of the Coltheart and Leahy (1996) wordlists (see Table 19), it was apparent that NS presented with difficulty in correctly reading irregular words, which was in marked comparison with his normal phonological skills. NS's score on the irregular words placed him comfortably in Band A (indicating a definite deficit) for irregular word reading. In clear comparison, his score on regular words placed him just in Band B (borderline performance). Finally, on nonwords, NS's score placed him in the Normal category for his age group. The clear discrimination between NS's normal ability in reading nonwords and his extreme difficulties in reading irregular words identified him as a clear case of developmental surface dyslexia.

NS’s difficulties in reading irregular words are clearly evident in his frequent regularisation errors, which he produced even when reading irregular words of relatively high frequency. On his initial reading of the Coltheart and Leahy (1996) wordlists, out of his 21 errors made when reading irregular words, NS made 9 regularisation errors, with some words of relatively high frequency, including NS reading ‘iron’ as “I-ron”, ‘come’ as “come” and ‘island’ as “is-land”. Another type of error frequently made by NS was letter orientation confusions with the letters ‘b’, ‘d’ and ‘p’ when reading words and nonwords, for example, in the Coltheart and Leahy (1996) wordlists, NS read ‘bick’ as “duck”, ‘pump’ as “bump” and ‘pretty’ as “bretty”.

Background information - WB.

WB was aged 10 years 11 months at the beginning of Experiment 2. He is of New Zealand Samoan descent with a New Zealand European mother and a Samoan father. WB was born and has grown up in New Zealand his entire life. His parents separated approximately two years ago and WB has found this very difficult. He currently lives with his mother and sister, and sees his father at weekends. WB speaks English with both his parents and speaks a small amount of Samoan when visiting his grandparents. WB generally spends his afternoons at sport practice or at home, watching television and playing on the computer.

Following the initial background testing, WB was found to have a WISC-III Full Scale IQ of 92, with his Verbal IQ score of 83 significantly lower than his Performance IQ of 103. Table 21 presents WB’s subtest scores from the WISC-III. It is notable that WB generally attained average or slightly above average scores for the Performance subtests (except for Block Design) and all his Verbal subtests are slightly below average, with Vocabulary the lowest.

Table 21.
WB's subtest scores for the WISC-III.

Verbal tests		Performance tests	
Verbal IQ	83	Performance IQ	103
Information	7	Picture Completion	10
Similarities	8	Coding	11
Arithmetic	9	Picture Arrangement	10
Vocabulary	5	Block Design	9
Comprehension	6	Object Assembly	12
Digit Span	8		

WB's reading age score on the Burt Word Reading test (8.01-8.07) was clearly lower than his chronological age (10.11 years). Overall, WB's reading presented as very slow, and he appeared to be trying very hard to work out the nonwords by attempting to find similarities with other words.

On his initial reading of the Coltheart and Leahy (1996) wordlists (during the initial background testing), it was apparent that WB presented with difficulty in sounding out unfamiliar regular words and all nonwords, in comparison with his normal age-related reading of irregular words. WB read 19/30 of the regular words correctly, and 3/30 of the nonwords correctly, placing him in Band A (indicating a definite deficit) for his age group for both regular and nonword reading. His particularly low nonword reading score places him very clearly in Band A for nonword reading. In clear comparison, WB read 18/30 of the irregular words correctly; placing him in the Normal category for his age group. The clear discrimination between WB's normal ability in reading irregular words and his extreme difficulties in reading nonwords identified him as a clear case of developmental phonological dyslexia.

WB's difficulties in 'sounding out' are evident in his frequent lexicalisation errors made when reading nonwords. On his initial reading of the Coltheart and Leahy (1996) wordlists, out of his 27 errors made when reading nonwords, WB made 10 lexicalisation errors, including reading 'bick' as "brick", 'crat' as "craft", 'doash' as "dash" and 'brinth' as "bright".

Background Testing

Method

Participants.

The two selected individuals identified above; NS and WB completed the Background Testing.

Materials.

Materials were as for Experiment 1, with the exception that the following tests were omitted:

Visual
- BORB Minimal Features subtest

Verbal
- Olson Homophone Choice
- ITPA Sound Decoding
- ITPA Sight Decoding
- PALPA Minimal Pairs – word
- PALPA Minimal Pairs – nonword
- PALPA Nonword Repetition

As a result, the testing materials included in Experiment 2 are as follows:

Visual:
- Benton Visual Retention Test
- Kaufman Gestalt
- Stanford Binet bead memory subtest
- ETS Identical Pictures
- BORB Overlapping & Non-overlapping letters and pictures
- Visual and Auditory Number Span

Visual-Verbal and Verbal	- Castles & Coltheart (1996) Homophone Matching	
	- Illinois Tests of Psycholinguistic Abilities	
		- Sight Spelling subtest
		- Sound Spelling subtest
		- Sound Deletion subtest

Procedure.

Following selection of the two chosen participants, the families of each child were contacted to assess whether they would be interested in their child being involved in the treatment programmes. Both families consented, and the range of pre-tests were administered across three weeks, in sessions during school time, or after school, in School A's meeting room. The background tests were administered in the same general order as Experiment 1, according to available time.

Results

The background tests were divided into visual, visual-verbal and verbal. The results for the Visual tests are presented in Table 22. NS attained high scores across the Visual tests, performing at an above average level for the Benton Visual Retention Scale, the Kaufman Gestalt and the Stanford Binet bead memory subtest. On the same subtests WB attained slightly lower scores than NS, but remained at an average level. For the BORB non-overlapping and overlapping letters and pictures, both NS's and WB's overall times slightly increased when the letters or figures overlapped. For the Visual and Auditory Number Spans, NS recalled the same length for both, whereas WB recalled a slightly longer length when the numbers were presented auditorally rather than visually.

Table 22
Visual tests (dyslexia subtype noted next to child's name)

Child	NS (SD)	WB (PD)
Benton Visual Retention Test		
Number Correct (/10)	8	6
Expected score (/10)	5	4
Number Error	2	4
Expected score	7-8	9
Kaufman Gestalt (scaled)	12	10
Stanford Binet Bead memory (SAS)	64	53
ETS Identical Pictures (/96 max)	66	58
BORB subtests:		
Non-overlapping letters -Time (sec)	0.79	0.84
Overlapping letters – Time difference cf. Non-overlapping letters (sec)	+0.16	+0.35
Non-overlapping Pictures – (sec)	2.23	1.45
Overlapping Pictures – Time difference cf. Non-overlap pictures (sec)	+0.37	+0.15
Visual No. Span (Max. length correct)	6	4
Auditory No. Span (Max. length correct)	6	5

Results from the Visual-verbal and Verbal skills tests in Experiment 2 are presented in Table 23. On the Castles and Coltheart Homophone Matching task, NS attained notably lower scores for two subtests: 1) when the target was a regular word and the foil was also a regular word (such as been/bean), and 2) when the target was an irregular word and the foil was a nonword (such as choir/quiar). In comparison, WB attained a fairly consistent level of scores across subtests, with his highest score when the target was an irregular word and the foil a nonword (such as choir/quiar). On the three subtests of the ITPA (2001): sight spelling, sound spelling and sound deletion, both NS's and WB's scores are in line with predictions based on their developmental dyslexia subtype features, with NS attaining a very low score for the sight spelling (spelling of irregular words), a slightly higher score for sound spelling (spelling of nonwords) and a very high score (well above average) for the sound deletion. On the other hand, WB attained a very low score for the sound spelling and sound deletion and a slightly higher score for sight spelling.

Table 23
Visual-verbal and Verbal tests

	NS (SD)	WB (PD)
Castles &Coltheart (1996) Homophone Matching:		
Regular target – Reg foil (e.g. bean/been) (/60)	31	47
Reg target –Irreg foil (e.g. berry-bury) (/30)	21	23
Irreg target – Reg foil (e.g. hymn-him) (/30)	21	19
Irregular target – Nonword foil (/30)	16	25
Illinois Tests of Psycholinguistic Abilities (2001):		
Sight Spelling (scaled)	4	7
Sound Spelling (scaled)	7	4
Sound Deletion (scaled)	13	4

Summary and Comments

The Background Testing identified three key differences between the two case studies. Firstly, on all of the Visual subtests, the participant with surface dyslexia, NS, attained slightly higher scores than the participant with phonological dyslexia, WB. Secondly, on the Castles and Coltheart Homophone Matching task, WB attained notably higher scores for two of the subtests. Thirdly, NS and WB attained notably different scores on ITPA subtests, in concordance with what would be expected given their dyslexia subtypes.

On all the Visual subtests, including the Kaufman Gestalt subtest, NS consistently attained slightly higher scores than WB. The finding is not consistent with results from Experiment 1, and does not support the hypothesis that developmental surface dyslexia would be associated with some visual difficulties.

In contrast, on the Castles and Coltheart Homophone Matching test, WB attained the higher scores for two of the subtests. The first of these involved selecting the regular target from a regular foil, a task that relied on the individual referring to their visual word recognition within the orthographic lexicon to identify which of the phonologically-matching letter strings is a real word and which is a nonword. The second subtest where WB also attained a higher score involved selecting the irregular word from a nonword foil, designed to phonologically match the targetted word. Again, this subtest relies on the individual accessing their Orthographic Input Lexicon to correctly identify the irregular word as the target. If the individual relies on their Nonlexical route for reading, they will sound out the irregular word and nonword target and incorrectly identify the nonword as the target. NS's lower scores on the Regular target – regular foil and the Irregular target – nonword foil subtests suggest he is relying on his nonlexical route for reading. These results are virtually identical to the results on the same test attained by MI, the surface dyslexic described by Castles and Coltheart (1996), for whom, following these findings, it was concluded that such results strongly suggest some impairment at the orthographic input level. The consistency of NS's results with MI's performance provides further support to the cognitive-neuropsychological subtyping approach to dyslexia: that surface dyslexia is a specific subtype of developmental dyslexia characterised by engagement of the Nonlexical route for reading to a greater extent than the Lexical route.

On the ITPA subtests of the visual-verbal and verbal tests, overall results were as would be expected - NS (the surface dyslexic) attained higher scores for the sound-related tests (sound spelling and sound deletion) than for the sight spelling test, and vice versa for WB (phonological dyslexic). These results are relatively consistent with the hypothesis that the poor nonword reading observed in phonological dyslexics is underpinned by poor phonological skills (Bradley & Bryant, 1983; Harm & Seidenberg, 2001; Hulme & Snowling, 1988).

Chapter 5: Experiment 2 - Training Programmes

Method, Procedure and Data Analysis

Participants.

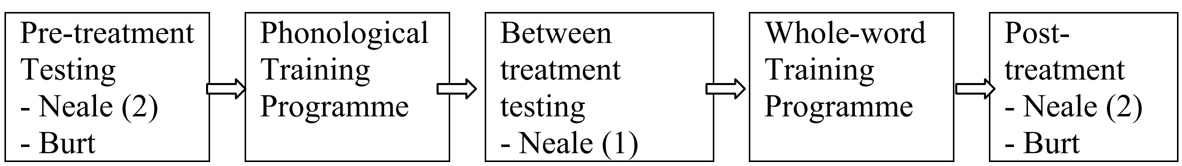
The two selected individuals, NS and WB, who participated in Background Testing for Experiment 2, continued with the training programmes.

Overall Training

Materials and Procedure

The children completed the following procedure, as outlined in Figure 11. Both children completed the training programmes in the order shown:

Figure 11. Overall training procedure for Experiment 2.



As in Experiment 1, the children's general reading performance was assessed before and after receiving each training programme using the Burt Word Reading Test and the Neale Analysis of Reading Ability. In the case of the Neale, Form 2 was again used for both overall pre- and post-treatment testing and Form 1 was administered between the two treatment programmes.

For Experiment 2, the training sessions began immediately following the completion of the background testing, and were conducted individually for each child. Initially each child completed two sessions a week; one session during school time at a time determined by the classroom teacher, and one session after school in School A's meeting room. Due to time constraints, the number of sessions was increased to three sessions per week for each child's second training programme, with the additional session being conducted during school time. The final sessions of the training programmes were completed during the school holidays, at the children's homes.

As with Experiment 1, each child received a treat-sized chocolate bar and bag of potato chips at the end of each after-school session, and a $20 gift voucher at the completion of both programmes. The vouchers were sent to the parents with a final letter and some feedback on their child's progress (the percentage of words the child was reading prior to training, and their completion results). Information was also provided to the teachers and principal of School A, and the researcher visited the school to enable staff to discuss the results and ask any questions.

Phonological Training Programme

Materials.

As with Experiment 1, pre-programme reading performance was assessed using lists of regular, irregular and nonwords based on Coltheart and Leahy's (1996) wordlists. However, for Experiment 2, these wordlists were extended from 30 words in each list up to 60 words in each list, retaining the original words and nonwords. The additional 30 regular and 30 irregular words were matched as closely as possible to those in the original wordlists in terms of word frequency, wordlength and number of syllables. The 30 additional nonwords were created by simply altering one or two letters in each of the original nonwords. We will refer to these wordlists as the 'Phonological Generalisation Wordlists' (see Appendix N for complete wordlists).

Participants also completed a spelling test comprising 10 regular words, 10 irregular words and 10 nonwords, randomly selected from the Alternative Wordlists, which were extended for the Whole-word Training Programme in Experiment 2. We will refer to this as the ‘Phonological Generalisation Spelling test’ (see Appendix O). The words were presented in a randomised order.

As for Experiment 1, Lovett et al.’s (1994) Sounds component of her PHAB/DI Reading Training Program (see Appendix G) was administered to assess the child’s basic phonological awareness. Following this, the Grapheme-to-Phoneme Correspondence (GPC) Selection test was administered to determine the child’s 10 target GPCs (see Appendix H).

Procedure.

The procedure was as for the Phonological Training Programme used in Experiment 1, the only exceptions being that the words used to test generalisation were replaced with extended wordlists as outlined above, and the use of a Phonological Generalisation Spelling test. For the spelling test, the procedure was simple: each word and nonword was read aloud to the child, and a definition of the word was given, or, if it was a nonword, the child was informed it was a ‘made-up word’. The child was then asked to write the word into their exercise book.

Whole-word Training Programme

Materials.

As with Experiment 1, pre-Whole-word Training Programme reading performances were assessed using an alternative set of regular, irregular and nonwords designed to be as closely matched as possible to Coltheart and Leahy’s (1996) wordlists. The Alternative Wordlists from Experiment 1 were extended to include 60 words in each list, comprising the 30 words used in Experiment 1 plus 30 additional words in each category. These were regular, irregular and nonwords that were matched as closely as possible to the previous words in terms of frequency, word length and number of syllables, and were termed the 'Whole-word Generalisation Wordlists' (see Appendix P).

As with the Experiment 2 Phonological Training Programme, participants completed a spelling test comprising 10 regular words, 10 irregular words and 10 nonwords. This test comprised words randomly selected from the Phonological Generalisation Wordlists, termed the 'Whole-word Generalisation Spelling test' (see Appendix Q). The words were presented in a randomised order.

The set of target words used for training consisted entirely of irregular words with each of the participants trained on the entire list of 200 words. The 200 irregular words, which will be referred to as the 'Irregular Wordlist' was based on Broom & Doctor's (1995a) list of 144 Irregular Words (Appendix J). Some of the higher-frequency words were discarded and additional lower-frequency irregular words were added to reach the total of 200 words (Appendix R).

The 200 training words were divided into two blocks of 100 words each, which were balanced for word frequency (see Appendix S). Visual mnemonic flashcards, as used in Experiment 1, were constructed for each of the words contained in Block A. As previously, the visual mnemonic cards displayed the written word overlaid by a visual graphic which was designed to emphasise the shape of the letters, and, where possible, to relate the shape to the meaning of the word (see Appendix L).

Procedure.

For the Pre-testing phase, the procedure was as for Experiment 1, with the following exceptions. First, in addition to the Whole-word Generalisation Wordlists, each child completed a 30-item Whole-word Generalisation Spelling test, both prior to and following training. Administration of the Whole-word Spelling test followed the same procedure as for the Spelling test in the Phonological Training Programme. Second, each child completed the entire 200-word Irregular Wordlist, working down the entire list, with words ordered according to frequency.

The training phase proceeded as follows. The 200 words from Block A and B were further broken down into 10 sets of 20 words each, balanced to ensure each set contained words of an approximately equal range of frequencies. Over the following ten training sessions, each child was introduced to a new set of irregular words (see Appendix S). The training procedure for each of the word sets began with the same steps; the child was requested to read a flashcard with the word written on it. They were encouraged to try and read the word ("have a go") and if they read the word incorrectly, or failed to produce a response, it was read to them by the teacher. The child was asked to give the meaning of the word, and if they were unsure of the definition, they were asked to look the word up in a dictionary, then read the definition to the teacher. Following these initial steps, each wordset was trained according to one of two formats: Block A was trained using the Visual Mnemonics technique and Block B using the Degraded Images technique.

For sessions 2, 4, 5, 7 and 9, each of the five wordsets of Block A were trained using the Visual Mnemonic flashcards, as described above (see Appendix L). The visual mnemonic was discussed with the child, in relation to the meaning of the word, and the child was then requested to spell the word on the board with the plastic letters, without looking at the flashcard. The child then wrote the word in their exercise book.

Sessions 1, 3, 6, 8 and 10 trained each of the five wordsets of Block B, respectively, using the Degraded Images technique, as used in Experiment 1 (see Figure 10). For this programme, the words in the training set for that session were each presented on the computer screen in a highly degraded form. Then, following this, seven successive images of the word were presented every 1500ms, with each one less degraded than the previous, until the word became completely clear at 10.5s. Each successive image was accompanied with a beep. The child was requested to guess the word as soon as they thought they might know the answer, and not to worry about making mistakes.

For both Blocks A and B, after all of the twenty target words for the training session had been introduced, and trained using either the Degraded Images task or the Visual Mnemonic flashcards, the child then completed a Cloze task based on the words. The Cloze task was as for the Whole-word Training Programme in Experiment 1, but each session involved 2 sentences for each of the target words of the session (40 sentences in total).

Following the completion of the ten sessions of the Whole-word Training Programme, each child was readministered the Whole-word Generalisation Wordlists and was retested on the 200 target irregular words they were trained on. Their responses to both these tests were recorded.

Data analysis and statistics.

For each of the training programmes, the participant's data was combined and analysed to compare the overall effectiveness of the Phonological Training Programme and the Whole-word Training Programme on each individual's results. Simultaneous logistic regression analyses were conducted, incorporating item as a repeated measure. The model was fitted using Generalised Estimating Equations (GEE). Independent variables were Testing Phase (pre- or post-training programme) and Target Status (whether the word or nonword contained a target GPC or not). Parameter estimates reported in the text are chi-square values for Type III tests, based on empirical standard error estimates. Independent variables were Testing Phase (pre- or post-training programme) and Person (NS or WB). For the Phonological Training Programme, overall results were investigated first, then solely results for the words and nonwords containing each participant's Target GPCs.

Logistic regression analysis was also conducted to compare the extent of generalisation across the Phonological and Whole-word Training Programmes. Independent variables were Programme Type (Phonological Training Programme or Whole-word Training Programme), Wordtype (regular, irregular or nonword) and Testing Phase (pre- or post-training programme).

In addition to analyses of the overall training results, data from each training programme was also analysed individually. Following completion of the Phonological Training Programme, each child's performance on the GPC Selection test (total words correct) was analysed using simultaneous logistic regression, incorporating item as a repeated measure, as outlined above. Independent variables were Testing Phase, and Lexical Status (word or nonword). Each child's performance on the Phonological Generalisation Wordlists was also analysed using logistic regression. The independent variables were Testing Phase (pre- or post-training programme) and Wordtype (regular, irregular or nonword). Further analysis was conducted for each wordtype separately, to compare performance on the two testing phases (pre- and post-Training Programme). Any score changes on the Phonological Generalisation Spelling test were analysed using the Exact Fisher test.

Results from the Whole-word Training Programme were analysed similarly to the Phonological Training Programme results. Each child's performance on the 200-item Irregular Wordlist (total words correct) was analysed using simultaneous logistic regression, incorporating item as a repeated measure. Independent variables were Testing Phase (pre- or post-training programme) and Technique (Degraded Images or Visual Mnemonics). Each child's performance on the Whole-word Generalisation Wordlists was also analysed using logistic regression. The independent variables were Testing Phase (pre- or post-training programme) and Wordtype (regular, irregular or nonword). Further logistic regression analyses were conducted for each wordtype separately, comparing performance on the two testing phases. The Whole-word Generalisation Spelling test assessed the children's spelling of words and nonwords they had previously been exposed to (as they were sourced from the Phonological Generalisation Wordlists). This could have been a potential problem had we been assessing the children's scores in comparison with the Phonological Generalisation Spelling test, but rather, we were assessing any changes in scores, and also identifying any spelling trends exhibited by the participants. The significance of any score changes was determined using the Exact Fisher test.

Results: Experiment 2 Training Programmes

Overall Training

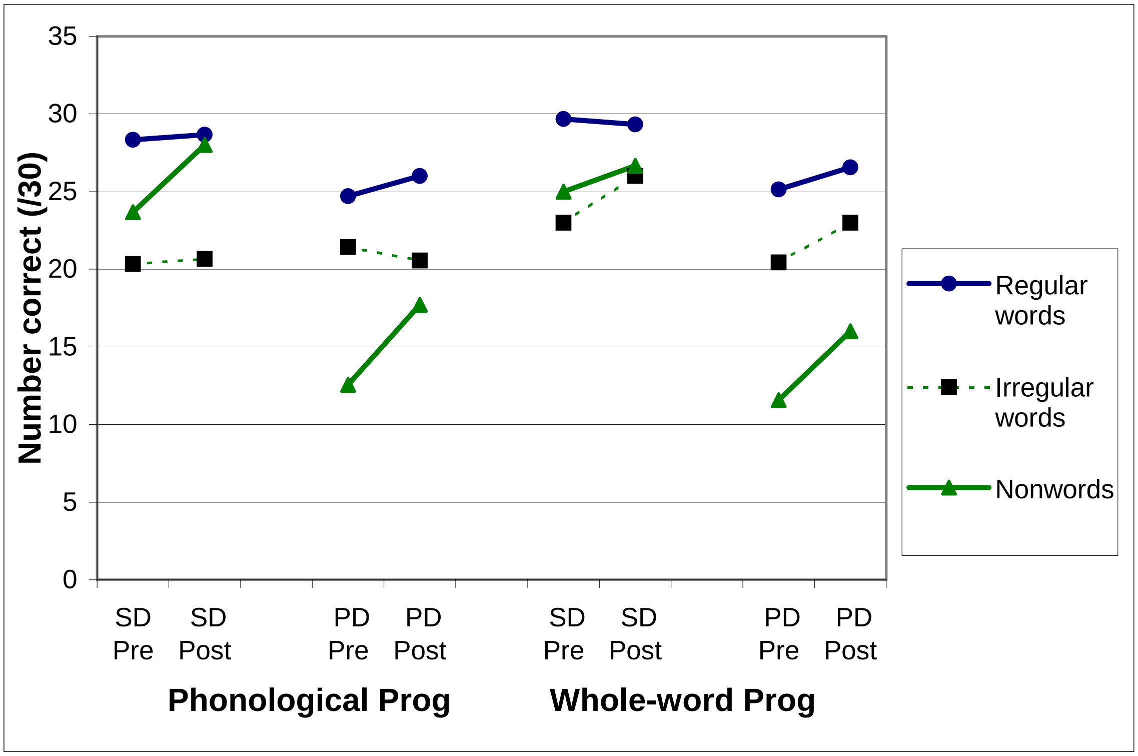
Results

Logistic regression analyses were conducted to compare the effectiveness that each of the Experiment 2 Training Programmes had on NS, a surface dyslexic, and WB, a phonological dyslexic. For the Phonological Training Programme, results indicated no significant interaction on the entire GPC scores between Testing Phase (pre- or post-programme) and Person (NS or WB) [$\chi^2(1)=0.01$, $p=0.904$]. When the Target GPCs were exclusively focussed on, there was again no significant interaction between Testing Phase and Person [$\chi^2(1) =0.03$, $p=0.861$].

For the Whole-word Training Programme, logistic regression analysis comparing NS's and WB's performance on the Irregular Wordlist indicated a highly significant interaction between Testing Phase (pre- or post-programme) and Person (WB or NS), [$\chi^2(1)=11.93$, $p<0.001$]. Scores indicate that NS, a surface dyslexic, made significantly greater improvement following the Whole-word Training Programme than WB, a phonological dyslexic. This is of note as the Whole-word Training Programme was NS's target programme, and he showed great response to this targetted intervention.

NS's and WB's scores for the Phonological Generalisation Wordlists and the Whole-word Generalisation Wordlists are presented together in Figure 12. The following trends are evident; both training programmes resulted in improvements on NS's regular, irregular and nonword reading scores, with his greatest improvement attained on his irregular word score following completion of the Whole-word Training Programme. In comparison WB showed only a slight improvement in his irregular word reading and a slight decrease in his regular and nonword reading scores following the Whole-word Training Programme. Following the Phonological Training Programme WB showed very slight improvement for his regular and irregular words, with a clear improvement in his nonword reading score.

Figure 12. Scores for the Phonological Generalisation Wordlists and Whole-word Generalisation Wordlists for NS (surface dyslexic: SD) and WB (phonological dyslexic: PD) pre- and post- completion of the associated training programme.



Logistic regression analyses were conducted on each child's combined scores on both the Phonological Generalisation and Whole-word Generalisation Wordlists, with the independent variables of Wordtype (regular, irregular or nonword), Testing Phase (Pre- or Post-training programme) and Programme Type (Phonological or Whole-word). NS, a surface dyslexic, showed significant main effects for Testing Phase [$\chi^2(1) = 17.60$, $p < 0.001$], Wordtype [$\chi^2(2) = 15.98$, $p < 0.001$] and Programme Type [$\chi^2(1) = 6.27$, $p = 0.012$]. NS's scores suggest that he attained higher scores following training, on regular and nonwords rather than irregular words, and for the Whole-word Training Programme. However no significant interactions between the independent variables were found. Of note is that the Whole-word Training Programme was the second programme completed by the participants, suggesting that NS's general reading ability may have been improving as a result of the one-to-one training he was receiving. WB's scores also showed significant main effects for all three independent variables: Testing Phase [$\chi^2(1) = 9.70$, $p = 0.002$], Wordtype [$\chi^2(2) = 75.67$, $p < 0.001$] and Programme Type [$\chi^2(1) = 6.75$, $p = 0.009$]. WB's scores indicate his nonwords score improved significantly following the Phonological Training Programme, while he made no significant improvement on any other wordlist following either training programme. This is confirmed by the logistic regression, which found a highly significant interaction between Testing Phase, Programme Type and Wordtype [$\chi^2(2) = 10.76$, $p = 0.005$].

As mentioned in the initial background information for NS and WB, each experienced key difficulties when reading their target words, which continued to challenge them throughout the training programmes. NS commonly made both regularisation errors, when reading irregular words, and letter orientation confusions, with 'b', 'p' and 'd'. There was little change in the frequency of these errors throughout the training intervention. In the Phonological Generalisation Wordlists pre-test, 17 of NS's 41 irregular word errors were regularisation errors, with 5 letter orientation confusions, and in the Phonological Generalisation Wordlists post-test, 18 of his 34 irregular word errors were regularisation errors with 13 letter orientation confusions. For the Whole-word Generalisation Wordlists pre-test, NS made 14 regularisation errors out of his 38 irregular word errors, with 4 letter orientation confusions, and in the post-test NS made 18 regularisation errors out of 28, with 5 letter orientation confusions. These tests indicate that, overall, approximately half of NS's irregular word reading errors were regularisation errors. Of note is that the majority of NS's remaining irregular word errors were refusals, where NS stated he was "not sure" of the word, then progressed to the next word. On the associated Phonological Generalisation and Whole-word Generalisation Spelling tests, NS continued to make regularisation errors for irregular words, for example, NS spelt ‘laugh’ as “larf”, ‘sure’ as “shor”, ‘work’ as “werk”. Letter orientation confusions were also present in his spelling, for example, NS spelt ‘simple’ as “simble”. The presence of NS’s regularisation errors provides further support for his reliance on ‘sounding-out’ words, rather than employing a whole-word approach, which is essential for reading irregular words.

In comparison, WB frequently made lexicalisation errors when reading nonwords, however this was observed to decline slightly following training intervention. On the Phonological Generalisation Wordlists pre-test, WB made 30 lexicalisation errors out of his 56 nonword errors, which reduced to 18 out of 42 nonword errors in the post-test. Examples of the lexicalisation errors made by WB in the Phonological Generalisation Wordlists include WB reading ‘ganten’ as “garden”, bleaner’ as “blender”, ‘trall’ as “troll” and ‘tield’ as “tired”. For the Whole-word Generalisation Wordlists pre-test, WB made 17 lexicalisation errors out of his 43 nonword errors, and in the post-test made 22 lexicalisation errors out of 46 nonword errors, including WB reading ‘bield’ as “believed”, ‘winten’ as “winter”, ‘troat’ as “toast” and ‘prumble’ as “plumber”. WB’s difficulty in ‘sounding-out’ was further evident when he was required to spell words and nonwords in the Phonological Generalisation and Whole-word Generalisation Spelling tests, and he wrote the correct letters but in an incorrect and unpronounceable format, for example WB spelt ‘lang’ as “lagn” and ‘garage’ as “gagrae”.

Throughout the training programmes the children’s overall reading ability was assessed and the results are presented in Table 24. Prior to beginning their first reading training programme, the children completed Neale 1 (Form 2) and Burt 1. At this point, the Burt Reading test revealed that both NS and WB were reading at a level two years behind their chronological age. This was generally supported by the Neale 1 Analysis Accuracy scores, which were similar. Following completion of their first training programme - the

Phonological Training Programme, Neale 2 (Form 1) was administered to the children. NS showed an improvement in his reading age by 6 months, however WB showed a slight decrease of two months. Following completion of the Whole-word Training Programme Neale 3 (Form 2) was readministered, with NS again showing a slight increase of three months, and WB showing a very slight improvement of one month, but still not meeting his earlier level attained for Neale 1. The Burt Word Reading test was also re-administered at the completion of both training programmes (approximately three months after the first administration). NS showed an improvement of 18 months in his reading age, while WB showed a lesser improvement of nine months, however still greater than the three months accounted for by elapsed time.

Table 24.

Burt Word Reading test and Neale Analysis (Accuracy) scores before, between and after completion of training programmes. Chronological ages at time of test completion are presented in brackets.

	NS (SD)	WB (PD)
Burt 1 – Pre Programmes		
-reading age	6.09-7.03 (10,11)	8.01-8.07 (10,11)
Burt 2 – Post Programmes		
-reading age	8.03-8.09 (11,02)	8.10-9.04 (11,02)
Neale 1 – Pre Phonological Training Programme	6.09 (10.11)	7.10 (10.11)
Neale 2 – Post Phonological/ Pre Whole-word Programme	7.03 (11.01)	7.8 (11.0)
Neale 3 – Post Whole-word Training Programme	7.06 (11.02)	7.09 (11.02)

Teacher/parent evaluations of reading improvement.

Again, as with Experiment 1, although no significant improvements in general reading ability were observed following completion of both training programmes, feedback provided by teachers and parents commented on changes they had observed; overall the key areas of change were in the child's reading, their confidence, and their willingness to read.

"(He) appears to be more confident with his reading during class." (WB)

"(He) is more confident to read in groups and to read part of the school newsletter." (NS)

" An increased willingness to get involved" (NS)

"His (general) confidence (is) better" (WB)

"I have noticed (he) is reading a chapter book, which in the past he may not have been willing to read out of school" (NS)

"(He) is more willing to read" (NS)

Phonological Training Programme

Results

Results following completion of the Phonological Training Programme are presented in Table 25. As for Experiment 1, both the entire GPC scores (out of 200) and the target training scores (out of 100) are presented. Additionally, for Experiment 2, the results are further analysed according to lexical status; words or nonwords.

Table 25.

Pre- and post-programme scores for the GPC Selection test, with percentage improvements.

	NS (SD)			WB (PD)		
GPC Selection test (/200)	Pre	Post	Imprvt	Pre	Post	Imprvt
- Overall	131	169	29%	72	125	74%
- Word	67	87	30%	43	66	53%
- Nonword	64	82	28%	29	59	103%
Target GPCs (/100)						
- Overall	50	78	56%	16	50	213%
- Word	23	37	61%	11	29	164%
- Nonword	27	41	52%	5	21	320%
Nontarget GPCs (/100)						
- Overall	81	91	12%	56	75	34%
- Word	44	50	14%	32	37	16%
- Nonword	37	41	11%	24	38	58%

The results indicate that both NS and WB performed better following completion of the Phonological Training Programme. These results are presented individually below, initially the Entire GPC Selection test, and then any generalisation observed on the Phonological Generalisation Wordlists and Phonological Generalisation Spelling test.

Overall, on the entire GPC Selection test, NS exhibited a tendency towards better performance post-training, particularly on his target GPCs, and considerably less so on the non-target GPCs. A logistic regression analysis investigating the variables Testing Phase (pre- or post-training programme), Target Status (containing target GPC or not) and Lexical Status (word or nonword), and any interactions between the variables was conducted. This revealed significant main effects of Testing Phase [$\chi^2(1)=10.08$, $p<0.01$] and Target Status [$\chi^2(1)=24.03$, $p<0.001$] on NS's performance, and a significant interaction between Testing Phase and Target Status [$\chi^2(1)=5.94$, $p<0.05$]. NS's scores indicate that he improved his reading of the words containing target GPCs significantly more than his reading of words containing non-Target GPCs, following completion of the Phonological Training

Programme. When NS's data was further analysed according to words and nonwords containing Target and non-Target GPCs, the score for the Target GPCs was found to have significantly improved following training [$\chi^2(1)=34.73$, $p<0.001$], however the non-Target GPCs did not show significant improvement [$\chi^2=0.46$, $p=0.498$]. Lexical Status (whether the items were words or nonwords) was found to have no significant effect on score for NS.

The Phonological Training Programme was WB's target training programme. Overall, on the GPC Selection test, WB's score improved from 72 up to 125 out of 200 following completion of the Phonological Training Programme. The improvements on the target GPCs do not account for this overall improvement, indicating further generalisation occurred to untrained GPCs. Logistic regression of WB's complete data for the GPC Selection test revealed significant main effects of Testing Phase [$\chi^2(1)=37.39$, $p<0.001$], Target Status [$\chi^2(1)=35.44$, $p<0.001$] and Lexical Status [$\chi^2(1)=4.33$, $p<0.05$]. The interaction between Testing Phase and Target Status was also significant [$\chi^2(1)=4.06$, $p<0.05$], with WB's scores indicating he improved significantly more in his reading of words and nonwords containing his Target GPCs following the programme, compared to his improvement on items containing non-Target GPCs. Solely analysing WB's performance on items containing his Target GPCs revealed significant main effects for both Testing Phase [$\chi^2(1)=26.27$, $p<0.001$] and Lexical Status [$\chi^2(1)=4.41$, $p<0.05$], with WB's scores indicating he significantly improved following the training programme, and that he was significantly more proficient at reading words, rather than nonwords. For the non-Target GPCs there was only a significant main effect for Testing Phase [$\chi^2(1)=10.94$, $p<0.001$], confirming that although WB made a significantly greater improvement on his target GPCs, there was further significant generalisation on the entire GPC Selection test. This is of note as NS only showed significant improvement on his Target GPCs and not his non-Target GPCs. This difference between the generalisation of the Phonological Training Programme attained by the two participants may be a result of the high base rates attained by NS.

Phonological Training Programme Generalisation Results

Scores for the Phonological Generalisation Wordlists are presented in Figure 12 (see above), according to Wordtype (regular, irregular or nonword) and Testing Phase (pre- or post-completion of the Phonological Training Programme). Reaction times for words read correctly both pre- and post- training programme are presented in Table 26, with results from the Phonological Generalisation Spelling test, according to Wordtype (regular, irregular or nonword).

Table 26.

Reaction Times for the Phonological Generalisation Wordlists, and scores for the Phonological Generalisation Spelling test. Difference between pre- and post-training programme scores and times also presented.

	NS (SD)			WB (PD)		
Reaction Times (s)	Pre	Post	Diffce	Pre	Post	Diffce
- Reg wds	2.95 (1.51)	3.12 (2.21)	0.17	1.16 (0.78)	1.00 (0.83)	(-0.16)
- Irreg wds	2.46 (0.97)	1.76 (0.66)	(-0.64)	1.18 (0.77)	1.13 (1.04)	(-0.05)
- Nonwords	8.44 (2.84)	6.14 (2.09)	(-2.3)	1.76 (0.48)	2.25 (0.86)	(-0.49)
Spelling (/10)						
- Reg wds	5	9	4	5	8	3
- Irreg wds	2	3	1	2	2	0
- Nonwords	3	5	2	1	1	0
- Total	10	17	7	8	11	3

Logistic regressions conducted on NS's data for the Phonological Generalisation Wordlists revealed a significant main effect of Testing Phase only ($\chi^2(1)=8.67$, $p<0.01$). When NS's results were analysed according to Wordtype, results indicated no significant improvement for any of the wordtypes; regular words ($p=0.072$), irregular words ($p=0.052$) or nonwords ($p=0.144$), following completion of the Phonological Training Programme. WB's overall performance on the Phonological Generalisation Wordlists also improved significantly following training. Logistic regression analysis revealed a highly significant main effect of Testing Phase [$\chi^2(1)=18.07$, $p<0.001$], however also showed a significant main effect of Wordtype [$\chi^2(2)=40.03$, $p<0.001$], and a significant interaction between the two variables [$\chi^2(2)=9.95$, $p<0.01$]. Analysis of each wordtype individually revealed a highly significant improvement in WB's reading of the nonwords [$\chi^2(1)=12.25$, $p<0.001$], but no other significant effects. This finding suggests that the skills trained in the Phonological Training Programme generalised well to WB's reading of untrained nonwords, but not NS's.

Table 26 shows reaction times for the participants' reading of the Phonological Generalisation Wordlists for all words that were read correctly both pre- and post-Training Programme. NS's mean reaction times for each wordlist suggest that NS was slower at reading the nonwords than the regular or irregular words. Although NS's mean reaction times according to Testing Phase suggest he improved his reading time for both the irregular words and nonwords, but slowed down his reading of regular words, paired sample t-tests indicate that none of the reaction time changes for any wordtype neared significance. WB's data showed very similar results. His mean reaction times according to wordlist indicate that he read the nonwords slightly slower than the regular or irregular words. Although WB's mean reaction times pre- and post-training suggest he slightly improved his reading speed of both regular and irregular words following training, paired sample t-tests indicate that no change in reaction time for any of the wordtypes neared significance. However, it is important to note that WB only read two nonwords correctly both pre- and post-Training Programme, so the effect cannot be considered reliable.

On the Phonological Generalisation Spelling test (presented in Table 26) NS's scores for the three wordsets indicate a notable improvement in his spelling of the regular words, with smaller improvements in both the nonwords and the irregular words. This provides some support for NS generalising his improved 'sounding-out' ability to assist him in spelling. The Exact Fisher test indicated that the probability of NS's Regular word scores pre- and post-completion of the Phonological Training Programme, neared, but did not reach significance ($p=0.065$), while the probabilities for the irregular and nonword scores were not significant. In comparison, WB's scores for the three wordsets of the Spelling test indicate a notable improvement solely in his regular wordset. The Exact Fisher test indicated that WB's scores on the Phonological Generalisation Spelling test did not approach significance for any of the wordlists. It is of note that although WB improved significantly on his reading of the nonwords, this did not generalise to his spelling of the nonwords.

Whole-word Training Programme

Results

Results from the trained irregular words in the Whole-word Training Programme are presented in Table 27. Table 27 presents the results for each child according to their training method (out of 100); either Visual Mnemonics or Degraded Images, then presents the total score (out of 200).

Table 27

Pre- and post-programme scores for irregular target words in Whole-word Training Programme, trained using Visual Mnemonics or Degraded Images techniques.

	NS (SD)		WB (PD)	
	Pre	Post	Pre	Post
Visual Mnemonics (/100)	24	69	45	74
Degraded Images (/100)	21	79	33	69
Trained words – overall (/200)	45	148	77	143

NS's scores for the trained irregular words are presented in Table 27. For words presented using the Degraded Images technique, NS correctly read the words following a mean number of 4.01 beeps (SD=1.60). Following completion of the Whole-word Training Programme, NS had improved his reading of the trained words by 229%. Logistic regression analysis revealed the main effect of Testing Phase to be highly significant [$\chi^2(1) =99.15$, $p<0.001$]. Both the Degraded Images and the Visual Mnemonic techniques resulted in significant improvements when considered separately (Degraded Images – [$\chi^2(1) =56.07$, $p<0.001$], Visual Mnemonics – [$\chi^2(1) =43.09$, $p<0.001$]). The Degraded Images appears numerically to have resulted in a slightly greater improvement, however the interaction between Training Technique (Degraded Images or Visual Mnemonics) and Testing Phase neared, but did not reach significance, [$\chi^2(1)=2.98$, $p=0.08$].

WB attained very similar results on the Whole-word Training Programme as NS. WB was slightly quicker at reading the words presented using the Degraded Images technique: the mean number of beeps was 3.12 (SD=1.37). Following completion of training, WB had improved his reading of the target irregular words from 77 up to 143 out of 200, an improvement of 86%. Logistic regression analysis revealed this improvement to be highly significant [$\chi^2(1) = 60.50$, $p<0.001$]. Both the Degraded Images and the Visual Mnemonic techniques resulted in significant improvements (Degraded Images – [$\chi^2(1) = 34.11$, $p<0.001$], Visual Mnemonics – [$\chi^2(1) = 26.47$, $p<0.001$]). The Degraded Images appears numerically to have resulted in a slightly greater improvement for WB, however the Training Technique (Degraded Images or Visual Mnemonics) did not have a significant interaction with Testing Phase, thereby indicating neither Technique was significantly more effective than the other.

Whole-word Training Programme Generalisation Results

Scores for the Whole-word Generalisation Wordlists, according to Wordtype (regular, irregular or nonword) and Testing Phase (pre- or post-completion of the Whole-word Training Programme) are presented in Figure 12 (see above). Reaction times for the Generalisation Wordlist words read correctly both pre- and post-training and results from the Whole-word Generalisation Spelling test, according to Wordtype (regular, irregular or nonword), are presented in Table 28.

Table 28.

Reaction Times for the Whole-word Generalisation Wordlists, and scores for the Whole-word Generalisation Spelling test. Difference between pre- and post-training programme scores and times also presented.

	NS (SD)			WB (PD)		
Reaction Times (s)	Pre	Post	Diffce	Pre	Post	Diff
- Regular words	4.45 (5.63)	3.09 (2.48)	(-1.36)	1.05 (0.65)	1.18 (1.10)	0.13
- Irreg words	2.73 (2.00)	2.32 (1.23)	(-0.41)	0.95 (0.47)	1.08 (1.06)	0.13
- Nonwords	6.01 (2.98)	5.30 (4.28)	(-0.71)	1.63 (0.86)	2.53 (2.40)	0.90
Spelling (/10)						
- Regular words	5	5	0	4	5	1
- Irregular words	2	4	2	4	7	3
- Nonwords	7	7	0	3	3	0
- Total	14	16	2	11	15	4

Logistic regression analysis was performed on the results from the Whole-word Generalisation Wordlists. The independent variables were Testing Phase (pre- or post-training programme) and Wordtype (regular, irregular or nonword). Results indicated a significant main effect of Testing Phase [$\chi^2(1)=8.97$, $p<0.01$]. When each wordlist was analysed separately, NS showed a significant improvement only on the irregular wordlist [$\chi^2(1)=7.14$, $p<0.01$], not on the regular or nonwords. This is a highly notable finding as it suggests that NS generalised the whole-word reading skills trained in the Whole-word Training Programme to improve his ability to read untrained irregular words. As NS is a surface dyslexic, he has specific difficulty reading irregular words, so a significant improvement in his ability to take a whole-word approach is of great interest. At this point, it is also worth commenting on some qualitative features of NS's performance during the Whole-word Training Programme. Rather than fully adopting a whole-word approach to reading as a result of the training, NS appeared to increase his reliance on the following technique: he would first sound the word out according to GPC rules, and would then try to think of words he knew that sounded similar to that pronunciation, for example, NS would sound out a word such as ‘break’ as “breek”, then think for a moment before concluding it must be “break”.

WB’s performance on the Whole-word Generalisation Wordlists differed considerably to NS’s. As with the Phonological Generalisation Wordlists, WB attained a notably lower score for the nonwords than for the irregular and regular wordlists, which was revealed by logistic regression to be significant [$\chi^2(2) =36.70$, $p<0.001$]. However, his nonword score is notably higher than it was pre-Phonological Training Programme, which he completed first, indicating he has maintained some of the sounding out ability he learned in the earlier training programme. Following completion of the Whole-word Training Programme, logistic regression analysis revealed that Testing Phase did not have a significant main effect on WB’s data, indicating that WB did not make a significant overall change on the Whole-word Generalisation Wordlists [$\chi^2(1)=0.15$, $p=0.695$]. This was confirmed when each wordlist was analysed separately and WB showed no significant change on any of the wordlists, indicating WB experienced no significant generalisation followed completion of the Whole-word Training Programme. wordlists, which may be related to the Whole-word Training Programme focussing on the whole-word approach to reading, rather than breaking the word down and sounding it out.

Reaction time data for the Whole-word Generalisation words read correctly both before and after training is presented in Table 28. Numerically, NS improved his reaction times for reading the regular, irregular and nonwords wordlists following completion of the Whole-word Training Programme. A paired samples t-test was conducted to evaluate the impact of the Whole-word Training Programme on reading times. Although the regular word improvement neared significance ($t(32) = 1.826$, $p = 0.08$), NS did not attain a significant improvement on his reaction times for any of the wordlists. In comparison, WB's reaction times slowed numerically for all wordlists following completion of the Whole-word Training Programme, however paired sample t-tests indicated these changes were not significant.

Scores for the Whole-word Generalisation Spelling test are also presented in Table 28. NS maintained stable scores for both the regular and nonwords, but showed a slight improvement on his irregular word spelling, potentially coinciding with his significant improvement in irregular word reading. However, the Exact Fisher test indicated that NS's Whole-word Generalisation Spelling test scores did not approach significance for any of the wordlists. On the Whole-word Generalisation Spelling test WB maintained relatively stable scores for both the regular and nonwords, but showed an improvement on his irregular word spelling, which suggests the possibility of some generalisation. However, the Exact Fisher test indicated that WB's Spelling scores did not reach significance for any of the wordlists.

Discussion of Experiment 2 Training Programmes

The more selective analysis of two key cases of developmental dyslexia generated the following five major findings: First, both the Phonological and Whole-word Training Programmes were effective at improving trained words for both the phonological and surface dyslexic individuals. Second, there was no difference in the overall effectiveness of the Phonological Training Programme for the two participants, based on their scores for the trained GPCs. Third, the Phonological Training Programme resulted in significant generalisation for the phonological dyslexic, WB, but not for the surface dyslexic, NS. Fourth, the Whole-word Training Programme was more effective for target participant, NS (surface dyslexic), than for WB (phonological dyslexic), with NS showing a greater improvement on the trained irregular words. Fifth, the Whole-word Training Programme resulted in significant generalisation only for the surface dyslexic, NS, but not for the phonological dyslexic, WB. The findings related to the Phonological Training Programme will be discussed initially, followed by the Whole-word Training Programme findings, concluding with a comparison of the two training programmes for each of the participants.

Phonological Training Programme

The Phonological Training Programme resulted in similar outcomes as Experiment 1: both the phonological and surface dyslexics improved on reading words and nonwords containing the trained GPCs. Although WB, the phonological dyslexic, exhibited greater improvement numerically than NS, the surface dyslexic, on both overall and target GPC scores, individual analyses indicated that both participants improved significantly on both scores. The overall effectiveness of the Phonological Training Programme was compared for NS and WB, revealing no significant difference between how the surface dyslexic and the phonological dyslexic responded to the overall Phonological Training Programme. This is of note as the Phonological Training Programme was developed to specifically address the reading difficulties of the phonological dyslexic, WB. This finding does not support our hypothesis that individuals with phonological dyslexia would respond better to the Phonological Training Programme than individuals with surface dyslexia.

Generalisation resulting from the Phonological Training Programme can be examined by measuring overall improvement on the entire GPC Selection test, which included both trained and untrained GPCs. Although the trained GPCs accounted for virtually all of NS's entire GPC Selection test score improvement, WB showed significant improvement on his untrained GPCs. This lack of significant generalisation for NS may, as with the surface dyslexics in Experiment 1, be due to his higher base score attained in the GPC Selection pre-test, thereby resulting in there being less room for improvement. However, the higher overall improvement attained by WB compared to NS replicates the higher entire GPC improvements attained by the phonological dyslexics in Experiment 1, compared to the surface dyslexics. Our rationale behind the development of the Phonological Training Programme was to address a key reading difficulty that has been associated with phonological dyslexia; grapheme-phoneme transcoding. Therefore, the finding that the Phonological Training Programme had a greater impact for the phonological dyslexics than for the surface dyslexics, in terms of generalisation to untrained GPCs, is consistent with this framework and provides some support for our hypothesis that the phonological dyslexics would respond better to the Phonological Training Programme than the surface dyslexics.

The greater generalisation attained by WB on his untrained GPCs was further supported by his improvements in reading the nonwords in the Phonological Generalisation Wordlist. Although both NS and WB showed numerical improvement on the regular, irregular and nonwords following the Phonological Training Programme, the only significant improvement attained was by WB on the nonwords. This finding is consistent with the focus of the Phonological Training Programme; to improve the development of the Nonlexical route, on which the reading of nonwords is completely reliant. As phonological dyslexics are hypothesized to have an under-developed Nonlexical route, the Phonological Training Programme was clearly effective in training this route for WB, as evidenced by his improved nonword reading. Further analyses confirmed that WB's nonword improvement following the Phonological Training Programme was greater than any other improvement he made on any of the wordlists following either training programme. It is of note that, unlike Experiment 1, the reaction times on the Phonological Generalisation

Wordlists showed no significant change for either participant following completion of the Phonological Training Programme.

Further generalisation following the Phonological Training Programme was assessed by the scores attained on the Phonological Generalisation Spelling test. NS attained numerical improvements on all three wordsets, with his greatest improvement on the regular wordset. WB also improved his regular word spelling numerically, however it is of interest that he did not attain any improvement on his nonword spelling, despite the nonword reading improvement. It is possible that WB's nonword spelling score was so low prior to training (one out of 10 correct), that the small amount of training provided was simply not sufficient to engender substantial gains in his performance on this different task. Further training may be required before WB's improved sounding-out ability (as evidenced in his nonword reading) could impact on the more difficult task of spelling.

Whole-word Training Programme

The results from the Whole-word Training Programme also showed the same trend as for Experiment 1, with highly significant improvements for both NS and WB in their reading of the 200 trained irregular words following completion of the training. Although both NS and WB improved their reading of the trained irregular words, the overall improvements were notably lower than for the Whole-word Training Programme in Experiment 1, where all participants approached, or reached, ceiling. This may be due to two key differences between the Whole-word Training Progammes: Firstly, the amount and type of trained words was changed, from 50 regular and 50 irregular words in Experiment 1 up to 200 irregular words in Experiment 2. Secondly, previously trained words were revised at the beginning of each session for Experiment 1, but not for Experiment 2. This revision may have further assisted the learning and recall of the trained irregular words.

Given the short period of time that is required for revision, this procedure could indeed be well worth the effort.

Both NS and WB showed a highly significant improvement on trained words for both the whole-word training techniques employed; the Degraded Images and the Visual Mnemonics. NS's numerical results suggest that the Degraded Images technique may have been slightly more effective for him than the Visual Mnemonics, however this difference fell short of statistical significance. The suggestion that the Degraded Images technique may have been at least as, if not more, effective than the Visual Mnemonics technique for NS, in training a whole-word approach to reading, is notable. As no previous research has been conducted employing this specific technique, this finding indicates that further research would be of great value to determine future worth of the Degraded Images technique in training the Lexical route for reading.

An overall comparison of the effectiveness of the Whole-word Training Programme for NS and WB revealed that NS improved significantly more on the trained words than did WB. This supports our hypothesis that individuals with surface dyslexia would respond better to the Whole-word Training Programme than would individuals with phonological dyslexia. Analysis of performance on the Whole-word Generalisation Wordlists indicated that, as with the Phonological Training Programme, significant generalisation was attained on the Whole-word Programme only by the 'target' participant; in this case, the surface dyslexic NS. Following the Whole-word Training Programme, WB showed no significant overall improvement on these wordlists. Indeed, his scores showed only slight numerical change, with his irregular word score slightly improving and the regular and nonword scores slightly decreasing. In comparison, NS showed a highly significant improvement overall, and specifically on the irregular words. Indeed, irregular words were the only type of words for which NS demonstrated significant generalisation, following either training programme. These findings, that NS showed significant generalisation following the Whole-word Training Programme, whilst WB did not, support our hypothesis that the Whole-word Training Programme would have a greater impact for the surface dyslexic than for the phonological dyslexic, in terms of generalisation to untrained words. The significant effect for irregular words in particular is consistent with the focus of the Whole-word Training Programme; to improve the development of the Lexical route, on which the reading of irregular words is completely reliant. Further generalisation was also suggested by the scores attained by the participants on the Whole-word Generalisation Spelling test. Although not significant, the trends mirrored those of the reading, with both individuals making numerical improvements virtually exclusively on the irregular wordset.

NS's significant generalisation to reading untrained irregular words following the Whole-word Training Programme is highly notable. As none of these irregular words was trained within the Programme, NS's significant improvement indicates that the skills trained in the Whole-word Training Programme are generalisable. This significant generalisation following the Whole-word Training Programme was not present in Experiment 1, and is inconsistent with the original case study that the Whole-word Training Programme has been partly based on (Broom & Doctor, 1995a). Although Broom and Doctor found that their student did significantly improve his reading of trained irregular words, this ability did not generalise to untrained irregular words. However, the finding of generalisation following whole-word training does support Brunsdon et al.'s (2002b) finding in their case study of TJ, a developmental mixed dyslexic. However, as noted in the Discussion of Experiment 1, Brunsdon et al. measured generalisation using regular words, not irregular words, so the precise functional locus of the improvement in this case is less clear.

The current finding of generalisation to untrained irregular words also counters Weekes and Coltheart's (1996) concept that training in reading irregular words can generalise to improved reading of untrained irregular words only if the words were premorbidly available. This would imply that such generalisation can only occur for acquired surface dyslexics, as developmental surface dyslexics have not developed the appropriate level of ability to read irregular words. However in the current study, following whole-word training, NS exhibited significant generalisation to reading untrained irregular words, which he had not previously read correctly.

As with the Phonological Generalisation wordlists, the reaction times for both participants on the Whole-word Generalisation wordlists showed no significant change. However, across both training programmes, WB was notably quicker than NS on all wordtypes and across wordlists, both before and after training. This difference in reading speed was also evident in the Degraded Images exercise, where WB was consistently faster than NS at identifying the word, despite both participants having received specific training for the word prior to the task. A similar trend was observed in the detailed case analyses presented in Experiment 1, where the phonological dyslexic was quicker than the surface dyslexic at identifying words presented in the Degraded Images task. As discussed in Experiment 1, this finding may reflect traits of the dyslexia subtype; WB, the phonological dyslexic, is skilled at using the Lexical route for reading, which is generally quicker than the Nonlexical route (Seymour, 1986; 1987a). In comparison, NS, the surface dyslexic, is not skilled at using the Lexical route, as indicated by his poor irregular word reading, which may have resulted in his slower recognition of the degraded word.

However, it is unclear as to why NS showed no improvement in reaction time following completion of the Whole-word Training Programme, given the significant improvement and generalisation he exhibited. This lack of improvement in reaction time may suggest that NS's improved irregular word reading ability may not directly correspond to an increased reliance on employing the quicker Lexical route for reading, as is proposed by the cognitive neuropsychological dual-route model. Rather, there may be additional skills involved in irregular word reading, which are not directly related to the Lexical reading route. A possible explanation for NS's improved irregular word reading may be, as noted above, attributable to an overall change in reading approach. Following completion of the Whole-word Training programme, NS was much more aware of the presence of irregular words within the English language. As a result, although he often sounded each presented word out, if his produced pronunciation was not a real word or did not sound correct, he would then try to think of alternative similar-sounding words. Whilst this was an effective technique for many of the irregular words in the current programme, it would have limited effectiveness according to the individual qualities of each word. For example, this technique would not be effective when trying to read words such as 'grind', where sounding out the word gives another actual word, in this case "grinned", or words such as 'tongue', where the correct pronunciation is very different to the 'word' attained by sounding out the graphemes.

Another interesting feature of NS's general reading ability is the presence of letter orientation confusion errors, which have rarely been cited in previous literature regarding developmental dyslexia. However, Temple (1984) also noted the presence of such errors in her analysis of 10-year old developmental surface dyslexic, RB. These errors were present in both reading and spelling for both NS and RB. Such errors are unexpected in surface dyslexia, as surface dyslexics break each word down into individual components in the process of reading, rather than focussing on the overall wordshape, so it would be expected that they would recognise any differences between each letter. It would be of interest to investigate this further to determine whether there may be a correlation between developmental surface dyslexia and letter orientation confusion, and, if so, where this stems from.

Following completion of both training programmes, the two participants exhibited different responses to the overall reading ability assessments. NS showed a noticeable improvement in his reading age on both the Neale and the Burt, however, although WB showed some improvement on the Burt, he slightly declined on the Neale Analysis. This lack of improvement in reading age according to the Neale Analysis may be attributable to the current training programmes focussing on single-word reading, whilst the Neale Analysis focuses on text reading. However, as in Experiment 1, it is not possible to identify any overall improvement in reading ability.

Comparison of training programmes for NS and WB

As hypothesized, the Whole-word Training programme appeared to be the most effective for NS numerically, with him attaining an overall improvement of 229% on the trained irregular words. In comparison, on the items containing trained GPCs in the Phonological Training Programme, NS made a notably lower improvement of 56%. Similarly, NS exhibited significant generalisation following the Whole-word Training Programme. He significantly improved his overall score on the Whole-word Generalisation Wordlists following completion of the Whole-word Programme, and made significant improvement on the irregular wordlist. Following the Phonological Training Programme, NS exhibited little evidence of generalisation, with only a 12% improvement shown on items containing the untrained GPCs, which was not significant. Although he showed significant overall improvement on the Phonological Generalisation Wordlists, there was no significant improvement on any specific wordlist.

As with NS, WB's target training programme, the Phonological Training Programme, appeared to be more effective for him numerically, than the Whole-word Training Programme. On the Phonological Training Programme, WB improved 213% on items containing trained GPCs. This is notably more than his improvement of 86% on the trained irregular words in the Whole-word Training Programme. Following the Phonological Training Programme, WB attained a significant improvement on his non-target GPCs, indicating generalisation. Further indication of generalisation was made with WB's significant improvements on both the overall Phonological Generalisation Wordlists, and on the nonword wordlist. In comparison, WB showed no significant improvement on the Whole-word Generalisation wordlists, neither overall nor for any specific wordlist following completion of the Whole-word Training Programme.

Overall, a comparison of the effectiveness of the two training programmes for each of the participants suggests that, numerically at least, each participant appeared to be most responsive to their target training programme. This finding would further suggest support for the dual-route model's subtyping approach to dyslexia, where specific skills and difficulties have been identified as corresponding to a specific subtype. Furthermore, this finding suggests that treatment of individuals with dyslexia may be best approached by identifying their dyslexia subtype (through the application of tests such as Coltheart and Leahy's (1996) wordlists), then focussing treatment on the specific difficulties of their subtype. The current research has suggested that it may be beneficial for treatment of individuals with phonological dyslexia to include 'sounding-out' skills and GPC awareness, whereas effective treatment of surface dyslexia may include irregular word training and the process of a whole-word approach to reading.

Chapter 6: General Discussion

The current research investigated the associated skills and impairments of developmental phonological and developmental surface dyslexia, and compared and contrasted the effectiveness of two reading training programmes. The following key findings were obtained: 1) Analysis of a large sample of reading-delayed children revealed specific cases of developmental phonological and surface dyslexia, as determined by relative performance on nonword and irregular word reading. 2) Background Testing from both experiments indicated that phonological dyslexia appears to be associated with poor phonological awareness. Limited support was provided by Experiment 1 for the possible correlation between surface dyslexia and specific visual skills, indicating further research is required. 3) Results from both Experiment 1 and 2 indicated that both training programmes effectively trained the targetted words and GPCs to all participants. 4) Experiment 2 further showed that although both training programmes effectively trained the targetted words to all participants, the children tended to exhibit greater improvement on their target programme, according to their dyslexia subtype. 5) Generalisation was evident following the Phonological Training Programme in both Experiment 1 and 2, however the Whole-word Training Programme was only found to result in limited generalisation in Experiment 2. 6) In Experiment 2, the effectiveness of the Whole-word training techniques appeared to be varied, suggesting that it may be worth further investigating the efficiency and effectiveness of each technique in training the employment of the Lexical route. Each of these findings will be discussed in depth below, along with any related limitations of the current study and directions for future research.

Subtyping according to the dual-route model of reading

To be selected for participation in the current study, children were required to display a particular impairment in reading irregular words or reading nonwords. According to the dual-route framework of Coltheart and colleagues, such specific reading difficulties indicate the presence of specific subtypes of developmental dyslexia: a low irregular word reading ability is interpreted by the dual-route model as indicating a weak Lexical reading route (termed developmental surface dyslexia), whereas a low nonword reading ability is interpreted as indicating a weak Nonlexical route (developmental phonological dyslexia). This clear dissociation between reading abilities, and reading routes, was well-supported by the current research. From our total sample of 91 children who were administered the initial screening tests, 56 could be described as extremely reading-delayed, defined as a reading age at least 18 months behind their chronological age and a normed score of 8 or above on the Block Design subtest. From this sample, 15 individuals fitted our criteria for one of the specific dyslexia subtypes (phonological or surface dyslexia): that is, on the Coltheart and Leahy (1996) wordlists, they scored in Band A on the irregular word or the nonword list (indicating a definite reading deficit), but scored within the normal range on the other list. This finding, that approximately one in four reading-delayed children can be described as having relatively ‘pure’ phonological or surface dyslexia is consistent with previous research (Castles & Coltheart, 1993), which identified a similar rate of one in three reading-delayed children as meeting these criterion. The remaining children in the current study’s overall sample exhibited delayed reading of both irregular words and nonwords to a greater or lesser extent, suggesting they had difficulties with both of the dual-route model’s reading routes. Within this group, 33 individuals were identified as exhibiting a stronger ability for one reading route than the other, however not to such extreme differences, that is, they attained a Band A score for one wordtype and a Band B (borderline) for the other, or a Band B and a Normal score. Combining the frequency of 'pure' and 'impure' cases, the current study found that 86% of the sample of reading delayed children exhibited some degree of dissociation between their irregular word and nonword reading abilities. This finding is highly consistent with Castles and Coltheart's (1993) research, which found that 85% of their sample appeared to show some level of dissociation between their irregular word and nonword reading abilities.

Of the 15 children identified with 'pure' surface or phonological dyslexia in the current research, there was a clear imbalance between the frequencies of each dyslexia subtype. 14 children were identified as phonological dyslexic, and only one as surface dyslexic. This is in clear comparison to Castles and Coltheart's sample of 56 dyslexics, which was found to comprise 18 children with a strong dissociation between their irregular word and nonword reading ability: 8 of whom were phonological dyslexic, and 10 surface dyslexics. The lower rate of surface dyslexia in the current research compared to Castles and Coltheart's study may be attributable to sampling differences. Castles and Coltheart's sample was sourced from remedial reading classes and learning disabilities clinics, whereas the current sample was sourced from mainstream schooling, and so, to a larger extent, relied on the evaluation of classroom teachers, who are unlikely to have received specific training in the recognition of delayed reading. As surface dyslexia is specifically correlated with impaired whole-word reading, such children may be difficult to identify as, according to the dual-route model, they are still able to read the majority of presented words through employment of the Nonlexical route. In comparison, children experiencing difficulties with the Nonlexical route may potentially present as more obviously impaired to their teacher, as they are unable to read any new words, even regular, common words. As a result, classroom teachers may be more likely to recognise phonological dyslexics as having reading difficulties than surface dyslexics, which may partially account for the greater proportion of phonological dyslexics in the current sample.

As a result of the low incidence of surface dyslexics in our overall sample, a relatively small number of surface dyslexics were actually involved in the current treatment programmes (four out of 12 participants). This limited the development of strong conclusions regarding any correlations of specific abilities associated with surface dyslexia. A larger group of surface dyslexics would have given the group data greater power, enabling potential correlations to be investigated in greater depth, including the suggested correlation between visual difficulties and surface dyslexia.

An additional problem with the surface dyslexics was that those selected tended to be less 'pure' than the phonological dyslexia cases. Apart from NS in Experiment 2, the three surface dyslexic participants in Experiment 1 attained Normal scores for the nonword reading, and Band B (borderline performance) for the irregular words, rather than indicating a clear dissociation. This may have influenced some of the results, potentially failing to clearly indicate the associated attributes and abilities of individuals who have a specifically under-developed Lexical route for reading. Of course, this suggestion in itself raises the issue as to whether truly 'pure' cases of developmental surface dyslexia really do exist. Are there really children who are skilled at sounding-out words and nonwords, yet completely incapable of correctly reading any irregular words? Even NS, who attained the clear dissociation between irregular word and nonword reading was still able to read some irregular words correctly. It would seem highly unlikely for even a severe difficulty with whole-word reading to result in a complete inability to read irregular words; one would expect some extremely high frequency words to be read correctly even in the most severe case, merely by virtue of repeated exposure. In comparison, developmental phonological dyslexia is assessed by the reading performance of nonwords, which have not been previously encountered, and rely on the effective use of the Nonlexical route.

Nevertheless, issues of incidence aside, the current study indicated support for the existence of pure cases of both surface and phonological dyslexia, suggesting a clear dissociation between nonword and irregular word reading ability in developmental dyslexics. This finding is in contrast to some previous research, which has stated that all developmental dyslexics exhibit phonological difficulties (Wilding, 1989). In accordance with this, the dissociation provides support for the usefulness of the cognitive neuropsychological approach to developmental dyslexia (Coltheart et al., 2001). In accordance with the dual-route theory of reading (Coltheart, 1985), the two routes that an individual can use for reading (Lexical and Nonlexical) are separate and dissociable, hence one can be damaged, or, as in the case of developmental dyslexia, can fail to develop, while the other route remains unimpaired or develops normally. The dissociation between the reading routes, as indicated here by the dissociation between irregular word and nonword reading, indicates that the routes do not develop together, and not necessarily at the same rate. However, although the routes are separate and an individual with developmental dyslexia may rely more heavily on one route than the other, it is important to acknowledge that this does not mean that the other route does not develop at all, or that it is absent. In the current research, this is clearly not the case as the surface dyslexics were still able to read some irregular words, particularly those of higher frequency, while most of the phonological dyslexics were able to read a few basic nonwords.

Further support for the distinction between dyslexia subtypes can be provided by spelling ability (Castles & Coltheart, 1996; Curtis, Manis & Seidenberg, 2001). As seen in Experiment 2, spelling errors provide an additional, qualitative indication of dyslexia subtype: Phonological dyslexics commonly make errors where the word looks of a similar shape however is not phonemically possible, for example WB spelled the word ‘garage’ as “gagrae”. Such errors would be self-corrected when reading, but are present in spelling assessments. In comparison, surface dyslexics commonly spell irregular words in the phonetically appropriate way, for example NS spelled the word ‘laugh’ as “larf”.

The notable differences in the reading speed attained by participants according to subtype provides further support for the dual-route approach to subtyping of developmental dyslexia. In both Experiment 1 and Experiment 2, response times were assessed for the Generalisation Wordlists both prior to and following the training programmes. Although Experiment 1 showed no conclusive trends, the performance of our well-matched cases in Experiment 2 revealed that, across training programmes, NS, the surface dyslexic attained notably slower reaction times for words and nonwords than did WB. This finding of slower reading responses by surface dyslexics supports previous research by Seymour (1987a). Seymour suggested that reliance on a phonological reading approach, as would be expected in surface dyslexics, involves serially processing each grapheme, a process which is considerably slower than reading via the lexical route. However, the finding that NS was also slower on reading nonwords than WB is of note. According to the dual-route approach to reading, it would be expected that WB would be slower when reading nonwords, due to his Nonlexical route being poorly developed, as evidenced by his low accuracy when reading nonwords. It would be expected that WB would take longer than NS to apply the GPC rules required to sound out nonwords, as he is unfamiliar with the GPC rules and the additional required process of blending the phonemes together to create the nonword. A possible explanation for the discrepancy is that, rather than relying solely on the Nonlexical route for reading nonwords, WB may be employing elements of his better-developed, and quicker Lexical route to assist him. For example, consider WB’s reading of the nonword ‘bink’. Assuming that WB is engaging the Lexical route, the events would be as follows:

First, on presentation of the nonword, the neighbouring units of ‘bink’ within the Orthographic Lexicon would be activated; that is, any words that look similar in letter combination, such as ‘pink’, ‘sink’, ‘drink’. Support for the occurrence of this process was suggested on a few occasions when WB was very verbal about his cognitive processing when reading both nonwords and unfamiliar words: for example, when presented with the nonword ‘scarrow’ WB identified “that’s ‘row’ on the end… ‘sc-’, ‘scarecrow’”, and the unfamiliar word ‘seize’ “take away the ‘e’ and that makes it ‘size’, then put the ‘e’ back in again…” (unfortunately, for this word, WB’s break-down of the word was not able to assist him to correctly identify it). This potential employment of the Lexical route to assist in breaking down nonwords into recognizable orthographic neighbours would enable faster identification of the presented word or nonword. In comparison, the processing time required if relying on the Nonlexical route alone would be notably longer, due to the serial processing required for each grapheme. This may partially account for why WB, despite his poorly-developed Nonlexical route, was able to consistently read nonwords more quickly than NS, who processed nonwords relying on his accurate, but slower, Nonlexical route.

Analyses of the cognitive abilities of each of the participants across Experiments 1 and 2 revealed phonological dyslexia to be generally associated with poor phonological awareness, however there was no clear correlation between surface dyslexia and any of the cognitive abilities assessed in the current research. A potential correlation between visual difficulties and surface dyslexia was specifically investigated in the current research. This correlation was originally identified in Boder’s (1968) subtyping work, where surface dyslexia was identified as dyseidetic dyslexia (or Gestalt-blind), and was claimed to be due to such individuals having impaired visual memory for words. This lack of visual memory was stated as accounting for the observed reliance of surface dyslexics on sounding-out each word, rather than reading ‘by sight’. However, in the current study, the hypothesis that visual difficulties would be correlated with developmental surface dyslexia was not clearly supported. Results from Experiment 1 suggested there might be a connection, with two of the three surface dyslexics attaining the lowest scores on the Kaufman Gestalt subtest (assessing visual recognition and configuration) and the Stanford-Binet bead memory subtest (assessing visual sequential memory). However, the results from Experiment 1 may have been skewed due to the lower IQs of these two participants. Nevertheless, there may still be some validity to theses observations because these two individuals did not show across-the-board poor performance on cognitive tests, rather their difficulties appeared to be quite selective. In order to accurately compare the group data of the two subtypes of developmental dyslexia, future research involving two well-matched groups of developmental phonological and surface dyslexics is necessary, to limit potential interference from any extraneous variables, including IQ.

In clear contrast to Experiment 1, the results of Experiment 2 indicated that NS, the surface dyslexic, did not perform at a lower level on the visual tests than WB, the phonological dyslexic. In fact, NS attained higher scores on the majority of the visual tests (including the Kaufman Gestalt and Stanford-Binet bead memory). NS's performance on the Visual subtests is consistent with Castles and Coltheart's (1996) case study of MI, another very 'pure' case of surface dyslexia, who also performed well above average on assessments of visual memory and visual encoding ability. The finding of no clear correlation between surface dyslexia and visual difficulties is not consistent with previous research including the group study conducted by Bayliss and Livesey (1985) and the case studies reported by Goulandris and Snowling (1991) and Samuelsson et al. (2000). All these studies found surface dyslexics (referred to as dyseidetic by Bayliss and Livesey) to exhibit deficits in visual memory and/or processing abilities, to which the low level of whole-word reading was attributed.

The inconclusive findings regarding the foundations of surface dyslexia have resulted in the possibility being raised of surface dyslexia not representing a single cognitive dysfunction, but rather comprising a group of heterogeneous dysfunctions. According to the cognitive neuropsychological approach, each surface dyslexia subgroup could be accounted for by a specific area and/or step of the DRC model being impaired. Possible steps for impairment that could result in poor irregular word reading include: a failure to develop word-representations within the Orthographic Input Lexicon, a failure to develop links between the Orthographic Input and Phonological Output representations, and a failure to develop links between the Orthographic Input representations and the Semantic System. Each of these possible difficulties will be discussed below.

As suggested in Experiment 1, one possible surface dyslexia subtype may be correlated with poor visual memory, resulting in poor ability to store Orthographic Input representations. As irregular words are suggested to rely on this lexicon, this would inhibit the individual's ability to recognise irregular words. However, as suggested in Experiment 2, some surface dyslexics may have normal, or even above-normal visual abilities. The current research indicated that the semantic information appeared to be intact for the tested surface dyslexics, as they were able to understand the meaning of the presented words. A key example of this was provided by NS's post-training performance on the Irregular Wordlist in Experiment 2: when presented with the word 'ballet' NS responded "um, this is the word for the dancing that my sister does….. ballet!". This response suggests that NS's Orthographic Input representation for this word was developed as he was able to recognise it, and that his semantic representation had also developed, indicated by his ability to identify its meaning. NS's verbal processing while trying to read the word suggests he may have been hindered in connecting the Orthographic Input and Semantic System representations with the word's Phonological Output representation, thereby slowing down his pronunciation. NS's response only provides a hint of what may be underlying his difficulty employing the Lexical route. However, it does provide some direction for future research investigating the specific difficulties associated with surface dyslexia, that is, to also focus on the potential difficulty of creating Phonological Output representations and developing these connections. It would be of interest for future research into the treatment of individuals with surface dyslexia to focus on comparing the effectiveness of treatments that focus on strengthening different areas and steps within the Lexical reading route. This could provide further information regarding which parts of the route are impaired, by indicating which treatment type results in greater improvement on irregular word reading.

Further possible explanations for the presence of surface dyslexia in some individuals, in the absence of any visual memory difficulties, such as NS in Experiment 2 and Castles and Coltheart's (1996) MI, are described below. One explanation may be that such individuals developed their Nonlexical route appropriately in the early stages of learning to read, and then failed to progress on to the development of the Lexical route. This would result in a reliance on the Nonlexical route for reading, as the Lexical route has either failed to develop or has not received the required stimulation to activate it. However, it is not clear as to why such individuals fail to progress in their reading development. Possibly this dysfunction could be related to a specific cognitive process we haven't measured in the current research, or perhaps it is reading-specific, so is not evident in any task other than reading. Clearly, further research is required to investigate the nature of the reading routes, particularly the Lexical route, and how they develop, specifically whether any particular process is required in order for each route to develop and begin operation.

A potential cause underlying the failure of the Lexical route to develop that is suggested in Experiment 2 may be the content of early reading training. NS's suggested reliance on the Nonlexical route may have been influenced by his early training in reading being focussed on the regular language of Māori. As the Māori language does not contain any irregular words, the Lexical route, although quicker, is not required for correct pronunciation. This may have resulted in NS not activating or developing this route, instead solely relying on his Nonlexical route for reading. This suggestion, that early reading training in a more regular language may impact on the child's irregular word reading ability, appears to be supported by Coltheart et al.'s (1983) case study of a developmental surface dyslexic, CD, whose early reading training was conducted in French, which, although not a completely regular language, is more regular than English. When later required to read English words, it is possible that, similar to NS, CD had not developed her Lexical route to the required extent, and as a result exhibited impaired irregular word reading. Further research would be of value to investigate whether children who are initially trained to read in a more regular language are more likely to experience surface dyslexia when required to read in a more irregular language after the period of beginner reading training has passed. However, although the afore-mentioned concepts may provide rationales for poor irregular word reading amongst certain individuals, it cannot be ignored that other children in similar circumstances, e.g. being trained to read in a more regular language, do not develop difficulties in whole-word reading. According to the dual-route model, normally-developing individuals read by employing the quicker Lexical route, regardless of the regularity of the language. This implies that, despite these other potential explanations for NS's poor irregular word reading, he did have a specific difficulty. There might be a complex interaction between cognitive predispositions to poor development of the Lexical reading route and limited exposure to irregular words, such that certain cognitive profiles might result in surface dyslexia in some individuals, but not others. Again, future research into the precise nature of the source and impact of surface dyslexia is clearly required.

Training programmes – effectiveness and generalisation

Despite the differences identified between the two dyslexia subtypes, both the Phonological and Whole-word Training Programmes in both Experiment 1 and 2 were effective for both subtypes in training the targetted material. This suggests that both nonword and irregular word reading can be improved with specific training, regardless of both the child's previous ability, and their dyslexia subtype. According to the dual-route model of reading, this implies that, despite one reading route being underdeveloped, as claimed to occur in developmental dyslexia, it may still be responsive to development with the appropriate training. However, the basis for the improved reading of the trained irregular words and nonwords is currently unclear. When learning individual sets of words or specific GPCs, it is possible that any improvements may be more due to repeated exposure than to the specific training technique.

However, results indicated that, as well as effectively training targetted words and GPCs, both the Phonological and the Whole-word Training Programmes resulted in some improvement in the reading of untrained words in specific individuals, indicating repeated exposure does not completely account for any improvement. The Phonological Training Programme in both Experiment 1 and 2 was effective in improving the nonword reading score for all participants, both surface and phonological dyslexics, with some of the phonological participants also showing generalisation to both words and nonwords within the GPC Selection test that contained Nontarget GPCs. The GPC training employed in the current Phonological Training Programme adopted an implicit approach: rather than directly training each letter combination and the corresponding sound, the programme focussed on 'families' of words containing the same letter group and related sound. This procedure encouraged the children to draw comparison between the letter combinations and their related sounds, and then apply this knowledge to other words, as well as nonwords. The generalisation observed following completion of the Phonological Training Programmes, particularly for the phonological dyslexics, is consistent with many other phonologically-based reading training programmes (Brunsdon et al., 2002a; Lovett et al., 1994; O'Shaughnessy & Swanson, 2000; Seymour and Bunce, 1994; Williams, 1980, 1981), including Broom and Doctor's (1995b) programme, on which the current one is based. This consistency between training studies suggests that, according to the dual-route model, the Nonlexical route is responsive to specific training, and that the trained skills (sounding-out and breaking down words) are highly generalisable and applicable to untrained material.

Both subtypes exhibited numerical improvement on their nonword reading scores on the Phonological Generalisation Wordlists following completion of the Phonological Training Programme in both Experiments. However, the analyses of the carefully matched cases in Experiment 2 revealed a subtype-specific effect that the phonological dyslexic showed significant improvement in nonword reading, while the surface dyslexic did not. This lack of significance for the surface dyslexic may be attributable to the high base rate attained for the nonwords, leaving little room for improvement. However, this suggestion is countered with the results of our back-up surface dyslexia case (CP, presented in Appendix T), who attained an even higher base rate than NS, yet still achieved a significant improvement in nonword reading. Therefore, rather than NS's lack of significant improvement in nonword reading being attributable to his higher base rate, a more specific reason for his performance is required. Possibly, his trained GPCs did not correspond with many of the nonwords within the Generalisation wordlist, thereby limiting any evidence of generalisation. Again, further research is required with a balanced proportion of

Generalisation nonwords corresponding to either the trained GPCs, or completely untrained GPCs, to enable a clearer indication of the nature and extent of generalisation.

Unlike the Phonological Training Programme, the Whole-word Training Programme only resulted in extremely limited generalisation, specifically for the surface dyslexics. Following completion of the Whole-word Training Programme, PS's performance (surface dyslexic case study in Experiment 1) suggested he may have improved his whole-word focus as he made paralexical errors in the degraded images exercise, rather than making regularization errors, which are more commonly expected of surface dyslexics. NS showed a clearer generalisation following the Whole-word Training Programme as he showed significant improvement on the Generalisation irregular wordlist. In comparison these results were not evident for the phonological dyslexic cases studied in detail in Experiment 1 and 2: MT and WB. The majority of research involving whole-word training has failed to obtain significant generalisation to untrained irregular words (Broom & Doctor, 1995a; Weekes & Coltheart, 1996). In the light of this, PS's lack of generalisation is not unexpected, and it is NS's generalisation to untrained irregular words that is surprising. Irregular words are idiosyncratic by nature, therefore general rules cannot be applied to determine their pronunciation. Within the dual-route model of reading, irregular words can only be read using the Lexical route, where each word requires a specific representation within the Orthographic Input Lexicon. In order to store a representation of a new irregular word within the Orthographic Input Lexicon, children need to have encountered the specific word before, in writing. The child must have heard the word read aloud to make the correspondence between the printed word and its pronunciation, stored in the Phonological Output Lexicon. Once the word has an orthographic lexical entry, when next presented with the word, the child is able to access this entry and its corresponding Phonological Lexical entry and is able to read it correctly.

Within the Orthographic Input Lexicon, there is no cross-over between lexical entries: each entry is independent and not grouped with other words. For this reason, generalisation appears unlikely to occur on the Lexical route, therefore we are unlikely to see any improvement on untrained irregular words.

So how can NS's generalisation to untrained irregular words be explained? Although the results suggest that the Whole-word Training Programme improved the functioning of NS's Lexical reading route, this is not a clear conclusion. NS's improved irregular word reading may instead have resulted from his changed reading style. Following the Whole-word Training Programme, NS clearly improved his irregular word reading and generalisation, however he appeared to have benefitted in quite a different way than would be expected. When presented with any wordtype; regular, irregular or nonword, NS initially broke the word down into graphemes and read the word slowly, according to its GPCs. If NS found the pronunciation difficult to produce, or if it sounded slightly familiar, NS then attempted to think of any similar-sounding real words. This approach may have resulted from his learning that many words are irregular, and vary slightly from their expected pronunciation. NS's response suggests that rather than adopting a whole-word approach to reading and employing the Lexical route, NS was continuing to rely on his Nonlexical route. This finding indicates that further research into the generalisability of Whole-word Training is required.

The Whole-word Training Programme resulted in overall changes in reaction times for the Generalisation wordlists, according to dyslexia subtype. Following the Whole-word Training Programme, the surface dyslexics' reaction times for all wordlists generally decreased, whereas the reaction times for the phonological dyslexics increased for all the wordlists. This discrepancy is of interest, as it suggests that the Whole-word Training Programme had different implications for the two subtypes. One possible explanation is that surface dyslexics began to focus on the word as a single unit, employing the quicker Lexical route for reading. In comparison, it is possible that the phonological dyslexics, who were already employing the Lexical route for reading, slowed following completion of the Whole-word Training Programme due to the development of their conscious awareness of focussing on the word as a single unit. As a result, they would have been actively seeking key features within the wordshape to aid word recognition.

As stated earlier, spelling errors provide a qualitative indication of the child's reading focus, whether it is whole-word or phonological. They can further indicate any observed changes in reading pattern, for example the phonological dyslexic beginning to make phonetically appropriate spelling errors suggests the child is developing their Nonlexical route. Therefore future research including spelling tests of a greater number of regular, irregular and nonwords of matched frequency and length would provide greater assistance in determining whether there has been generalisation of the trained reading skills to the child's spelling ability, as well as potentially providing a signal of any overall changes in reading technique.

The low number of training sessions conducted for each of the training programme may have limited any possible impacts of training. Development of each reading route may require further training before it has any impact on the child's reading ability of specific wordtypes. Further research involving a larger number of sessions would be of interest to investigate the extent that training period impacts on learning, particularly generalisation. Furthermore, it would be beneficial to conduct any future research with groups of phonological and surface dyslexics that are well-matched for variables such as IQ, age and reading ability. This is important as it is possible that these variables may interfere with the effectiveness of the training programmes in the following ways: i) children with lower IQ may be less responsive to the training as they may require additional training prior to recognising new words or applying new skills; ii) older children may find it more difficult to develop their weaker reading route than younger children, due to having relied on the alternative route for a longer period of time and being more likely to have developed compensatory measures; iii) differing pre-training reading abilities may impact the post-training level to which children are able to achieve.

Although both training programmes resulted in all participants, regardless of dyslexia subtype, significantly improving their reading of the targetted material, most developmental dyslexics are not as 'pure' as the current participants. That is, rather than a clear dissociation between irregular word and nonword reading ability, developmental dyslexics generally exhibit a more generalised reading disability. So, what does the current research tell us about training developmental dyslexics in general? The analysis of extreme cases was useful in the current research as they exemplified both ends of the spectrum of reading difficulties associated with dyslexia. As the training programmes resulted in general improvement for all of the 'pure' cases, regardless of prior difficulty, it would suggest that such programmes would be effective for all children in training the targetted material. The current research appears to support the value of identifying the child's specific reading difficulty and then tailoring the treatment accordingly. That is, if the child meets the requirements for a dyslexia subtype, administration of the relevant target treatment programme will specifically train their area of difficulty. Whereas, if the child exhibits difficulty across both irregular word and nonword reading, it would appear beneficial for the child to receive both treatment approaches to effectively train both reading routes, as skilled reading requires proficiency in reading both irregular words and nonwords or words that have not been previously encountered.

Evaluation of whole-word training techniques

The specific training techniques employed in the Whole-word Training Programme produced varied results that will now be discussed in greater depth. The Phonological Training Programme employed in the current study was essentially a replication of Broom and Doctor's (1995b) case study, and produced comparable results. In comparison, the Whole-word Training Programme partially replicated Broom and Doctor's (1995a) case study, but employed a number of different training techniques. Some of these techniques were sourced from previous case studies of developmental and acquired surface dyslexia, such as visual mnemonic flashcards. This technique focussed on increasing the participant's connection between the wordshape and the word's meaning. Under the cognitive neuropsychological DRC model, the Visual Mnemonic flashcards aimed to strengthen the connections between each word's representations in the Orthographic Input Lexicon, the Semantic System and the Phonological Output Lexicon. One of the other Whole-word training techniques was developed specifically for the current research: Degraded Images. According to the DRC model, the Degraded Images technique aims to get the child to focus on the word's Orthographic Input representation, as well as strengthening the connection between the word's Orthographic Input and Phonological Output representations by encouraging the child to provide the word's pronunciation as quickly as possible.

The format of Experiment 2 enabled the comparison between the effectiveness of the Degraded Images training technique, and the Visual Mnemonics, at least with respect to their effectiveness in training the targetted words. The rationale behind the development of the Degraded Images technique was that it could potentially draw the child's attention to the overall orthographic configuration of the word, within a context where graphemic analysis is discouraged (speeded responding). This could potentially enrich the visual specification of the word within the Orthographic Lexicon, making it more readily activated in response to the appropriate stimulus. Furthermore, the encouragement of speeded response may have assisted in strengthening the connection between the Orthographic Input and Phonological Output representations, thereby aiding the development of quicker response times for the trained words. In an evaluation of the participants' responsiveness to the two techniques, the numerical scores of both NS and WB suggested that the Degraded Images technique was more effective than the Visual Mnemonics in training irregular words across a range of frequencies.

Although our data found no significant effects of training technique on performance, further research into the Degraded Images technique might be worth pursuing for three primary reasons: 1) the Degraded Images technique was developed specifically for the current study, adopting an original procedure attempting to further develop the individual's focus on the whole-word units, and thereby increase their usage of the Lexical route for reading. Further research investigating the effectiveness of the Degraded Images technique would be of great value to determine its future worth in training irregular word reading. 2) There was a trend towards greater improvements using the Degraded Images technique for both NS and WB, and was in fact significant for one of the back-up cases for Experiment 2 (for the remaining back-up case, there was no difference). 3) The potentially greater effectiveness of the Degraded Images technique may also provide support for a possible correlation between the presence of surface dyslexia, and weak or nonexistent Orthographic Input representations and/or connections between Orthographic Input and Phonological Output representations.

It is important to bear in mind, of course, that in neither experiment were the whole-word training techniques 'pure'; that is, both techniques were employed in conjunction with training using plain flashcards and cloze tasks. This raises the question of whether any of the training techniques employed in the Whole-word Training Programme were specifically helpful in training the Lexical reading route. In a comparison of the effectiveness of Visual Mnemonic and simple ‘word only’ flashcards in training irregular words, Brunsdon et al. (2002b) found that visual mnemonic flashcards were no more effective than ‘word only’ flashcards. This suggests that specific whole-word training techniques may have no significant influence on the effectiveness of the training of irregular words. However, the current research provides some hints that training technique could be important, with the Degraded Images technique appearing to be numerically more effective than the Visual Mnemonics flashcards. To reliably investigate the effectiveness of each of the training techniques, the Whole-word Training Programme may need to be further broken down: for example, four sets of matched irregular words could be trained with each set receiving a different training technique: A) plain flashcards, B) visual mnemonic flashcards, C) cloze tasks D) degraded images. The training techniques would need to be balanced to control for any potential confounding effects, with a potential training programme adopting the following format: a between-subjects design – Group 1: ABBA, Group 2: CDDC, then alternating the training techniques administered to each group. Furthermore, in the current study generalisation was assessed following completion of the entire Whole-word Training Programme, with its combination of Visual Mnemonics and Degraded Images sessions, thereby preventing any comparison of the generalisation resulting from each individual technique. To further assess the effectiveness of each training technique, it would be of interest to assess generalisation between each section of training. This would allow comparisons to be made between the effectiveness of each technique in training the Lexical reading route, for both trained and untrained words.

It may also have been of benefit to assess untreated irregular words that, unlike the irregular words assessed in the Alternative and Whole-word Generalisation wordlists, had been matched in frequency to the trained irregular words. The potential relevance of matched-frequency to the learning of irregular words relates to the process of storing and retrieving representations of irregular words from the dual-route model's Orthographic Input Lexicon. High-frequency words are more likely to have been encountered by the child beforehand and are more likely to be encountered again within a shorter time period than low-frequency words, which are rarely encountered. As a result, high frequency words have been suggested to have higher resting levels of activation, that is, they need relatively less stimulus input to reach a state of activation. Such words are more readily accessed in the Orthographic Input Lexicon than words of lower frequency. Furthermore, as the child is more likely to have encountered words of higher frequency in an oral context, they are more likely to have a richer semantic representation for such words, thereby further aiding word recognition.

Assessments of overall reading ability

Although both training programmes effectively trained the key skills to the participants, completion of the two training programmes appeared to have a varied impact on each child's general reading ability, as assessed by standard reading tests. It is of note that these reading assessments were administered at the very beginning and very end of training, so therefore do not discriminate between the training programmes. General reading ability was provided by both a single-word assessment (the Burt Word Reading test) and a text reading assessment (the Neale Analysis of Reading Ability), with age-related norms provided for each. Although some children notably improved their reading age following completion of the training programmes, others showed a slight decline. The results from the single-word Burt assessment showed improvement for each child ranging from six months up to almost two years, with the length of both training programmes totalling less than six months, thereby indicating further improvement than that accounted for by time. However, results from the text-based Neale Analysis demonstrated results ranging from a decline of two months, up to an improvement of two years. This variation between participants partially supports previous research that has investigated the impact of phonological training programmes on reading ability. Wise and Olson (1995) found that, despite significant improvements in students' phonological awareness and decoding skills following training, there were no significant improvements in reading age assessments.

The varied results according to the reading tests suggest that the more specific the measure of reading ability, that is, the more it isolates the skill that was trained, the more likely it is to pick up any improvements resulting from the training. As both training programmes in the current research focussed on single-word reading, it is unclear whether this training would be expected to have any effect on text reading ability. The limited scope of the current research in terms of number of sessions and, as a result, number of trained words/GPCs, may have limited any potential general reading improvement. It appears likely that the training would need to be administered for a longer time period and cover a much larger training set before any benefits would become apparent on more ecologically valid measures such as text reading.

Further limitations of the current study and directions for future research

In addition to the limitations mentioned above, two further general limitations were also apparent, concerning the comparability of participants, and the programme structure. Discussion of these limitations follows.

The differing abilities both between and across participants according to dyslexia subtype resulted in the phonological dyslexic and surface dyslexic children attaining very different baseline scores on both the training programme wordlists, and on the generalisation wordlists. The phonological dyslexics attained much lower scores for nonwords, while the surface dyslexics attained similar scores to the phonological dyslexics on the irregular words, but much higher scores on nonwords. This difference in baseline scores means that there were wide differences in the opportunity for improvement, which may have impacted the results. It is difficult to counter this limitation whilst retaining standard training material across participants, however a few options are possible: 1) investigation of a wider sample of children could focus on matching baseline scores to ensure greater comparability across participants and dyslexia subtypes. 2) Case study research involving individual training wordsets matched to each individual's ability would provide an indication of the individual's improvement. This would limit direct comparison between individuals or subtypes, but could potentially provide an indication of the effectiveness of the training programme for a specific level of ability. 3) Data could be analysed to determine the potential room for improvement, e.g. if a child attained 45 out of 60, they would have a 15-point potential improvement, whereas another child who attained 13 out of 60 would have a 47-point potential. Accordingly, rates of improvement could then be determined by determining the child's percentage improvement on their potential, e.g. if the child had a 15-point potential and read an additional 5 correct, they would have made a 33% improvement on their potential. In comparison, if the child had a 47-point potential and made the same 5-point improvement, they would have made a lesser 10% improvement. Again, as mentioned for previous limitations, this procedure would probably work best if the numbers of words tested was quite high, thereby providing larger numbers and greater distinction between participants and subtypes.

In order to further investigate whether the specific reading difficulties of each developmental dyslexic subtype would result in distinct responses to the training programmes, it would be useful to examine reading-level controls on a similar task. The importance of reading-level controls has been frequently argued (Bryant & Impey, 1986;

Stanovich et al., 1997). This is primarily due to the belief that there is nothing abnormal about the symptoms displayed by developmental dyslexics, particularly developmental surface dyslexics. It is argued by some authors that the poor irregular word reading ability exhibited by surface dyslexics is indicative of a general reading delay, and that, as a result, surface dyslexics skills are matched with younger normal readers (including Bryant & Impey, 1986; Manis et al., 1996; Stanovich et al., 1997). The symptoms associated with developmental surface dyslexia, including slower overall reading and a reliance on sounding words out, are claimed to be characteristic of the child's reading level, not a specific reading disability. As a result, the inclusion of data from reading-level controls enables comparisons to be made between the abilities of the dyslexics and those that would be expected according to their reading age, to determine whether there is any deviance between them. The inclusion of data from reading-level controls would be of particular relevance in the assessment of treatment effects, as a further measure of whether surface dyslexia is distinct from general developmental delay. This would potentially be shown by any difference between the patterns of responsiveness shown to the training by the surface dyslexics and the reading-level controls, and whether there were any clear trends between the groups.

The structure of the programmes was varied between Experiments 1 and 2. For Experiment 1, half the children received the Phonological Training Programme first and half received the Whole-word Training Programme, with balance between dyslexia subtypes. However, in Experiment 2, both key cases received the Phonological Training Programme first. This programme order may have influenced the children's responsiveness to the training and learning patterns. For example, NS, the surface dyslexic, commented that he was pleased he had completed the Phonological Training Programme first as he then knew more about sounding words out, and he could then use this to help him work out the irregular words in the Whole-word Training Programme. This potential limitation could be addressed in future research with each programme's training material being divided in half, and counter-balanced, for example 1) Whole-word A, 2) Phonological A, 3) Phonological B, 4) Whole-word B.

In conclusion, this study has further supported the usefulness of the cognitive neuropsychological approach to developmental dyslexia, in its account for the clear dissociation present between the irregular word and nonword reading abilities of the two subtypes of developmental dyslexia. This provides support for the presence of two separate routes for reading: the Lexical and the Nonlexical routes. The two training programmes developed to target these subtypes were effective for all individuals, regardless of subtype, in training the reading of targetted words. However, the comparison of two well-matched cases in Experiment 2 indicates that developmental dyslexics may attain larger improvements following a training programme targetted to their specific impairment than their non-target programme. The Phonological Training Programme was generalisable to untrained words, particularly for phonological dyslexics, however the Whole-word Training Programme showed limited generalisation, only for one of the surface dyslexics. Overall, the reading programmes developed for the current study provided a short-term effective intervention, assisting a range of children who have experienced difficulty in developing reading skills. To address the key areas of difficulty present within the subtypes of developmental phonological and developmental surface dyslexia, the current research provides some limited support for the notion that it is beneficial to provide specific, tailored treatment programmes.

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Appendices

Appendix A: School A Classroom Identification Form

Teachers

Helen Rowse is in our school next week testing children for her PhD. She is looking at children with reading difficulties and trialling 2 treatments. The children selected will get some one on one help for approx 15 hours.
A notice is going home today to the children, what I need from you is the full names of any children who fit the following criteria and the most suitable time nest week to withdraw them for testing. Testing will be in the meeting room one on one and take approximately 15 minutes.
The children must be working at Level 3 in maths and be at least 1 year or more behind their chronological age in reading, cannot be NESB pupils.
The results of the reading test will be given to you and should be OK for you to use on your reports.

Child's Full Name	Room Number	Most suitable testing times

Appendix B: School A Parent Information notice

26th October 2001

Dear Parents/ Caregivers

During the next week, Helen Rowse from Victoria University will be based at our school. Helen is currently working on her PhD on childhood reading difficulties and their treatment. She will be testing some children and the ones that fit a certain criteria will benefit form some one to one assistance with their reading.

If you do not want your child involved in this programme please ring the school office. If you particularly would like your child involved please ring Mary Wootton at the above number.

Thanking you

(Reading Teacher)

Appendix C: Coltheart & Leahy's (1996) reading test

Regular words	Irregular words	Nonwords
Bed……………..	Blood………………	Aspy………………
Brandy………….	Bouquet……………	Baft……………….
Chance………….	Bowl……………….	Bick………………
Check……………	Break………………	Bleaner……………
Chicken………….	Brooch…………….	Boril……………….
Context…………..	Ceiling…………….	Borp……………….
Cord……………...	Choir………………	Brennet…………….
Curb………………	Colonel…………….	Brinth………………
Drop………………	Come………………	Crat………………...
Flannel…………….	Cough……………..	Delk………………..
Free……………….	Eye…………………	Doash………………
Hand………………	Friend……………...	Drick……………….
Life………………..	Gauge……………	Farl………………...
Long………………	Give……………….	Framp……………..
Luck………………	Good………………	Ganten……………..
Market……………..	Head……………….	Gop………………..
Marsh………………	Iron………………..	Grenty……………..
Middle……………	Island………………	Gurve………………
Mist………………..	Lose………………..	Hest………………..
Navy……………….	Meringue…………..	Norf………………..
Need……………….	Pint………………...	Peef………………...
Nerve………………	Pretty………………	Peng………………..
Peril………………..	Routine…………….	Pite…………………
Plant………………..	Shoe………………	Pofe………………..
Pump………………	Soul………………..	Rint………………...
Stench……………...	Sure………………..	Seldent……………..
Tail………………...	Tomb………………	Spatch……………...
Take ……………….	Wolf……………….	Stendle……………..
Weasel……………..	Work……………….	Tapple……………...
Wedding…………..	Yacht………………	Trope………………
Correct: …./30	Correct …./30	Correct …./30

Appendix D: Test Reliability and Validity Information

- Burt Word Reading Test

Gilmore et al. report a Kuder-Richardson reliability coefficient (KR 20) of 0.96, 0.97 and 0.97 for groups of 6.03 to 6.09, 8.03 to 8.09 and 10.03 to 10.09-year-olds, respectively. Test-retest reliability between administrations one week apart ranged from 95% to 99% (Gilmore et al., 1981). Pearson's correlations were determined between children's performance on the Burt Word Reading Test and three related tests; the PAT: Reading Comprehension, Reading Vocabulary Tests and the Test of Scholastic Abilities (Gilmore et al., 1981). The correlation coefficients ranged from 0.51 to 0.87. Further Pearson's correlations were determined between the Burt and the Schonell Graded Word Reading Test; these ranged from 0.90 to 0.98 (Gilmore et al., 1981).

- Neale Analysis of Reading Ability

Testing procedures for the Australian analysis of the Neale were conducted with 1394 students ranging in age from 6 years to 13 years (McKay & Barnard, 1999). Parallel forms reliability tests were conducted for Forms 1 and 2 of the Neale Analysis – 3rd Edition, and, across the age groups, the rate, accuracy and comprehension reliability coefficients were 0.91, 0.97 and 0.93 (respectively), all of which are statistically reliable above the 0.001 level of confidence (McKay & Barnard, 1999). Internal consistency reliability coefficients (KR 21) were calculated for both Forms of the Neale Analysis – 3rd Edition for Rate, Accuracy and Comprehension. The coefficients, averaged across the age groups, were 0.95 and 0.94 for Rate, 0.96 and 0.95 for Accuracy, and 0.86 and 0.87 for Comprehension (for Form 1 and 2 respectively) (McKay & Barnard, 1999). Concurrent validity was determined by correlating Neale subtest scores with scores from the Schonell Graded Word Reading Test (Schonell & Goodacre, 1974) and the Vocabulary and Similarities subtests of the WISC-R (McKay & Barnard, 1999). Pearson product moment correlations averaged 0.86, 0.58 and 0.55 for the Schonell, Vocabulary and Similarities tests respectively.

- Benton Visual Retention Test

Interrater reliability for Administration A of the BVRT is very high, with cited studies ranging from 0.90 to 0.98 for both the total Number Correct Score and the Total Number Error Score (Sivan, 1992). Both simple correlational analysis and factor analysis have been utilised to assess the validity of the BVRT, concluding that performance on Administration A reflects both general short-term memory ability and a visuoperceptual analytic ability (Sivan, 1992).

- Kaufman Assessment Battery

Reliability testing of the entire Kaufman Assessment Battery for Children found that odd-even reliabilities within one-year age groups averaged from 0.70 to 0.90 for subtests, and 0.85 to 0.95 for global score (Kaufman & Kaufman, 1983). Test-retest reliabilities were computed over intervals of two to four weeks; for the subtests they ranged from 0.59 to 0.98, and for global scores, ranged from 0.77 to 0.97.

- Stanford-Binet (Fourth Edition)

Reliability assessments for the entire test battery, employing the Kuder-Richardson technique, yielded reliabilities ranging from 0.95 to 0.99. Test-retest reliability data from a limited sample of 57 5-year-olds and 55 8-year-olds, identified coefficients of 0.91 and 0.90 (Thorndike et al., 1986).

- The Kit of Factor-Referenced Cognitive Tests

The Kit of Factor-Referenced Cognitive Tests comprises 72 cognitive subtests focussed on assessing 23 aptitude factors (e.g. Flexibility of Closure, Word Fluency, Logical Reasoning). Mean and standard deviation data is provided for all subtests, conducted by Ekstrom et al. (1976), French, Ekstrom and Price (1963) and other cited studies.

- Castles and Coltheart (1996) Homophone Selection test

For the case study for whom they developed the test, Castles and Coltheart (1996) have collected control data for 10 male subjects, chronologically-matched to their target subject – a ten-year-old boy. The mean data for each subtest and the standard deviations were: Regular/regular words – mean=52.9 (SD=3.51), Regular/Irregular words – when the regular word was the target, group mean= 27.0 (SD= 2.45), and when the irregular word was the target, mean= 25.1 (SD= 1.91), and Irregular/nonwords – mean= 27.4 (SD= 1.95).

- Illinois Test of Psycholinguistic Abilities – 3rd Edition (ITPA-3)

Standardised scores for the ITPA are determined from raw scores; ranging from 1 (very poor) up to 20 (very superior), with scores from 8 to 12 indicating average level of ability. Extensive reliability and validity data is presented within the manual, indicating that the ITPA-3 evidences a high degree of reliability across three types of reliability – content, time and scorer differences. Sivan (2001) concludes that the magnitude of the reported coefficients strongly suggests that the test possesses little test error and that test users can have confidence in the results. Validity testing indicates that the ITPA-3 is a valid measure of spoken and written language and can be used with confidence (Sivan, 2001).

Appendix E: Parental Consent Form

CONSENT TO PARTICIPATION IN RESEARCH: PARENT'S FORM

Title of project: Cognitive analysis and remediation of reading disorders in children

Principal Investigator: Helen Rowse, Ph.D. Student, School of Psychology
Supervisors: Dr. Carolyn Wilshire and Dr. Richard Siegert, School of Psychology

I have been given a full explanation of this research project and have had an opportunity to ask questions and have them answered to my satisfaction. I understand that the project will involve an examination of the reading and cognitive capabilities of my child with the objective of obtaining further information about the nature of reading disorders in children and potential treatment programmes. I appreciate that the study is exploratory only and should not be seen as a form of therapy.

I understand that the data obtained may appear in graduate student reports, poster presentations, conference presentations and peer-reviewed publications, but that in all cases, my child will be referred to only by his or her reversed initials. I am aware that testing and remediation sessions will be recorded on tape and later transcribed. The identity of my child will be kept confidential to the researchers participating in this project. The data will be kept by Dr. Carolyn Wilshire in a secure place and destroyed after fifteen years. Summaries of the data (in a form that does not identify my child) will be kept by Dr. Wilshire, Dr. Siegert and Ms. Rowse and may be shared with other competent professionals on a case by case basis.

I understand that my child may withdraw himself or herself (or any information we have provided) from this project at any time without having to give reasons and without penalty of any sort.

I would/ would not like to receive a summary of the results of this research when it is completed (Please delete as necessary).

I agree that ____________________________, who is under my guardianship, may take part in this research.

Signed:_________________________

Name:__________________________

Date:______________

Appendix F: Child Consent Form

Children's reading

You are invited to take part in Helen's special project

For Helen's project she will be looking at children's reading and exploring ways of helping children learn to read better. If you want to help her with the study she will play reading games with you which most children find fun. You can stop whenever you want. The games will be taped and then Helen will write down what you have said. Then Helen will write about what you have told her. Nobody else will be told your name.

What do I do now?

Tick the boxes if the words are true

- I know all about the project ☐
- I know I can leave at any time ☐
- I know what I say will be taped ☐

Yes, I'd like to take part ☐

No, thankyou ☐

Name:______________________________

Appendix G: Phonological Awareness Test

Phoneme	**Associated word**
a	ant
m	ham
s	bus
e	eat
r	bar
d	mad
f	stuff
i	if
th	this
t	cat
n	pan
c	tack
o	ox
a	ate
h	hat
u	under
g	lag
l	pal
w	wow
sh	ship
I	I, ice
k	tack
o	over
v	love
p	sap
ch	touch
e	end
b	grab
ing	sing
y	yard
er	brother
x	ox
oo	moon
j	jump
y	my
wh	when
qu	quick
z	buzz
u	use

Appendix H: GPC Selection test

1) carrow	ow
2) jure	u-e
3) creach	ea/ch
4) spray	ay
5) zeep	ee
6) squeal	ea/qu
7) lather	th
8) thoan	oa/th
9) squill	qu
10) trow	ow
11) vine	I-e
12) cray	ay
13) munch	ch
14) nauce	au
15) oath	oa/th
16) traunch	au
17) orphan	ph
18) pellow	ow
19) flate	a-e
20) littay	ay
21) meech	ch/ee
22) phantom	ph
23) voam	oa
24) prane	a-e
25) willow	ow
26) vable	le
27) winger	ng
28) meed	ee
29) chean	ea/ch
30) shriep	ie
31) missile	I-e
32) pumble	le
33) cheat	ea/ch
34) jingle	le/ng
35) rinture	u-e
36) sauce	au
37) keast	ea
38) wuckle	ck/le
39) scream	ea
40) slate	a-e
41) zingle	le/ng
42) mow	ow
43) slime	I-e
44) duke	u-e
45) ephin	ph
46) fable	le
47) squash	qu
48) faith	ai/th
49) staip	ai
50) ploak	oa
51) leech	ch/ee
52) poke	o-e
53) zow	ow
54) pother	th
55) squeap	ea/qu
56) pracket	ck
57) crane	a-e
58) stain	ai
59) croak	oa
60) farth	th
61) launch	au/ch
62) flake	a-e
63) grale	a-e
64) linger	ng
65) grape	a-e
66) phabe	ph/a-e
67) crow	ow
68) graud	au
69) tine	I-e
70) grief	ie
71) trime	I-e
72) groom	oo
73) hanger	ng
74) twipe	I-e
75) haul	au
76) noal	oa
77) haunt	au
78) siege	ie
79) hoke	o-e
80) muke	u-e
81) slood	oo
82) hurray	ay
83) janger	ng
84) screat	ea
85) jute	u-e
86) keel	ee
87) laith	ai
88) spoon	oo
89) jeep	ee
90) shriek	ie
91) mier	ie
92) prief	ie
93) quaint	ai/qu

94)	foast	oa
95)	ratch	ch
96)	mumble	le
97)	phase	ph/a-e
98)	choke	ch/o-e
99)	stripe	I-e
100)	pier	ie
101)	fray	ay
102)	quote	o-e/qu
103)	rack	ck
104)	cope	o-e
105)	remay	ay
106)	vulture	u-e
107)	foam	oa
108)	bissile	I-e
109)	relay	ay
110)	boast	oa
111)	wail	ai
112)	plake	a-e
113)	cure	u-e
114)	theft	th
115)	deed	ee
116)	anphan	ph
117)	proom	oo
118)	aphid	ph
119)	baint	ai
120)	barrow	ow
121)	baunt	au
122)	fraud	au
123)	beel	ee
124)	chote	ch/o-e
125)	beetle	ee/le
126)	quilt	qu
127)	bellow	ow
128)	brock	ck
129)	raisin	ai
130)	vunch	ch
131)	brood	oo
132)	quaist	qu/ai
133)	buckle	ck/le
134)	revise	I-e
135)	bute	u-e
136)	riege	ie
137)	smook	oo
138)	fope	o-e
139)	snack	ck
140)	pholo	ph
141)	snape	a-e
142)	cling	ng
143)	snay	ay
144)	waisin	ai
145)	spade	a-e
146)	photo	ph
147)	repise	I-e
148)	spook	oo
149)	dillow	ow
150)	crung	ng
151)	stole	o-e
152)	preach	ea/ch
153)	foal	oa
154)	stote	o-e
155)	quirt	qu
156)	pling	ng
157)	blay	ay
158)	stung	ng
159)	quone	qu/o-e
160)	pholtom	ph
161)	swack	ck
162)	bracket	ck
163)	sway	ay
164)	taul	au
165)	waunch	ch
166)	thatch	ch
167)	weetle	ee/le
168)	thert	th
169)	yeast	ea
170)	frock	ck
171)	bield	ie
172)	froop	oo
173)	fupe	u-e
174)	droop	oo
175)	fuse	u-e
176)	gack	ck
177)	quoon	oo/qu
178)	yield	ie
179)	zail	ai

Appendix I: Alternative Wordlists

Regular words	Irregular words	Nonwords
sat…………………..	war…………………	hain………………...
clinic……………….	geyser……………...	prane……………….
please………………	engine……………...	trool………………..
north……………….	ocean………………	virth………………..
prevent……………..	foreign……………..	sunten……………
despair……………..	villain………………	wist………………...
hook………………..	clue………………...	prite………………..
part…………………	limb………………..	scarrow…………….
nine………………...	none………………..	reetle……………….
display……………..	boulder……………..	troat………………..
soil…………………	gone………………..	vock………………..
land………………...	high………………...	quist………………..
side………………...	live…………………	slont………………..
call…………………	know……………….	bine………………
lack………………...	wool………………..	reep………………..
sister……………….	liquid………………	trang………………..
scarf………………..	dough………………	cloam………………
reason……………...	minute……………...	swull……………….
text…………………	bomb……………….	moof……………….
plug………………..	debt………………...	chike……………….
feet…………………	once………………..	phurp………………
nurse……………….	mayor………………	buke……………….
adopt……………….	shove………………	clemty……………..
least………………..	music………………	tribble……………..
cane………………..	acid………………...	maunch…………….
blares………………	bruise………………	greal………………..
wait………………..	rich…………………	bield………………..
name……………….	much……………….	snay………………..
possum…………….	diesel………………	stome………………
sixteen……………	circuit………………	jart…………………
Correct: ……/30	Correct: ……../30	Correct: ……../30

Appendix J: Whole-word Training
Programme Word Selection Test – Irregular Words

1. many
2. people
3. through
4. before
5. should
6. above
7. sure
8. group
9. warm
10. gone
11. heart
12. weather
13. friend
14. language
15. music
16. measure
17. natural
18. ocean
19. strange
20. store
21. business
22. minute
23. science
24. women
25. pretty
26. quiet
27. ancient
28. lady
29. believe
30. sugar
31. shore
32. salt
33. touch
34. none
35. pushed
36. fruit
37. liquid
38. usual
39. drew
40. rough
41. tongue
42. prove
43. quarter
44. foreign
45. orange
46. wool
47. worry
48. worse
49. canoe
50. washing
51. whistle
52. canal
53. rhyme
54. autumn
55. soup
56. flour
57. flood
58. ceiling
59. muscle
60. clue
61. uniform
62. shone
63. orchestra
64. mention
65. freight
66. medium
67. honest
68. vegetable
69. shepherd
70. echo
71. worm
72. scheme
73. crude
74. comb
75. stalk
76. chorus
77. scissors
78. fried
79. vehicle
80. ballet
81. marine
82. diary
83. chalk
84. pirate
85. schedule
86. dough
87. sew
88. seize
89. lettuce
90. pearl
91. colonel
92. angel
93. villain
94. recipe
95. gym
96. cough
97. exhaust
98. chemist
99. leopard
100. coward
101. fury
102. dread
103. plague
104. steak
105. parachute
106. choir
107. tomb
108. gown
109. budget
110. disguise
111. mechanic
112. senior
113. onion
114. mansion
115. trough
116. heir
117. super
118. eclipse
119. waltz
120. gem
121. sleigh
122. resign
123. bough
124. café
125. receipt
126. shove
127. tortoise
128. chore
129. cleanse
130. guilt
131. spinach
132. geyser
133. wrestle
134. pension
135. niece
136. bruise
137. crumb
138. beige

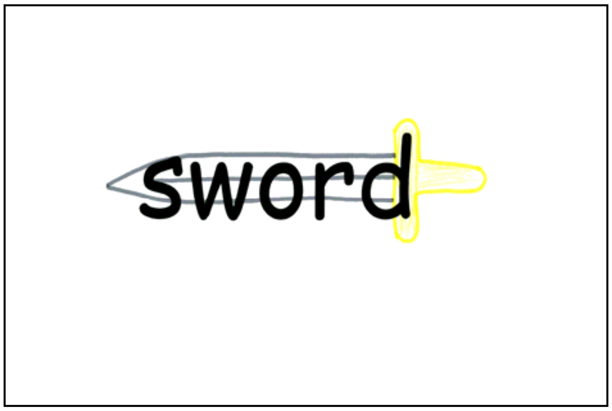
139. queue
140. suede
141. adore
142. typist
143. thyme
144. chasm
145. petite
146. puree
147. diaper
148. chaotic
149. mediterranean
150. lyrics
151. cymbal
152. matrix
153. plaits

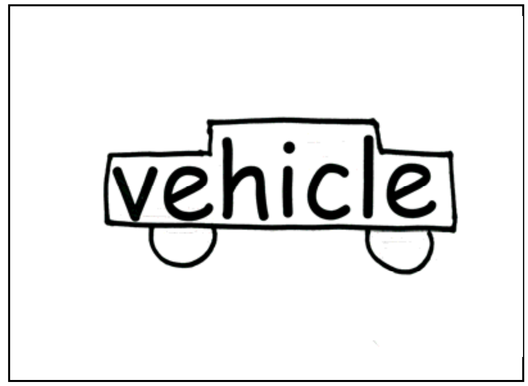
Appendix K: Whole-word Training Programme
Word Selection Test – Regular Words

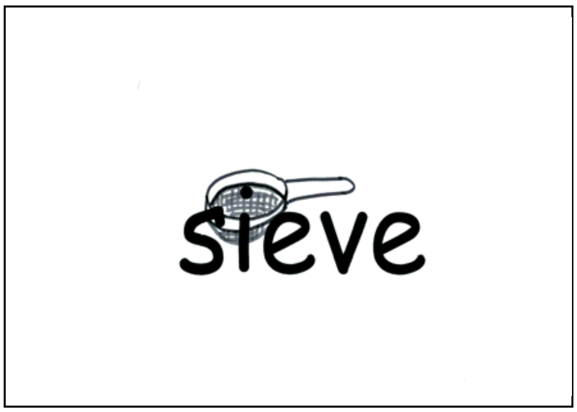
1) then
2) called
3) write
4) man
5) between
6) began
7) hard
8) sentences
9) held
10) moon
11) names
12) pattern
13) window
14) points
15) check
16) correct
17) horses
18) plane
19) eggs
20) sleep
21) exactly
22) object
23) cattle
24) afraid
25) thick
26) teeth
27) stick
28) meat
29) happen
30) desert
31) rose
32) steel
33) chair
34) spot
35) pointed
36) band
37) valley
38) steam
39) swim
40) serve
41) planets
42) holes
43) cream
44) replace
45) shadow
46) duck
47) pile
48) accident
49) flame
50) shelf
51) slave
52) depth
53) goal
54) habit
55) juice
56) midnight
57) blend
58) granted
59) width
60) mate
61) daylight
62) visitor
63) feather
64) extreme
65) companions
66) peculiar
67) slice
68) doubled
69) blade
70) jokes
71) hobby
72) scarce
73) shaft
74) rectangle
75) knives
76) fright
77) pottery
78) toads
79) bubble
80) buffaloes
81) lace
82) enjoyment
83) maid
84) spectacular
85) isolated
86) trout
87) cages
88) notion
89) puppet
90) vinegar
91) bowling
92) textiles
93) organic
94) tailor
95) summit
96) pluck
97) sneeze
98) darling
99) debate
100) carbohydrates
101) buzz
102) howl
103) removal
104) watermelon
105) mechanism
106) prose
107) toil
108) strawberry
109) offensive
110) portrait
111) fable
112) racket
113) trumpets
114) antelope
115) chunk
116) crate
117) breeches
118) engagement
119) tadpole
120) barefoot
121) unwilling
122) sash
123) staple
124) turnip
125) headlights
126) quack
127) thrifty
128) nephew
129) geckos
130) extinction
131) crusade
132) squawk
133) violation
134) easygoing
135) reinforce

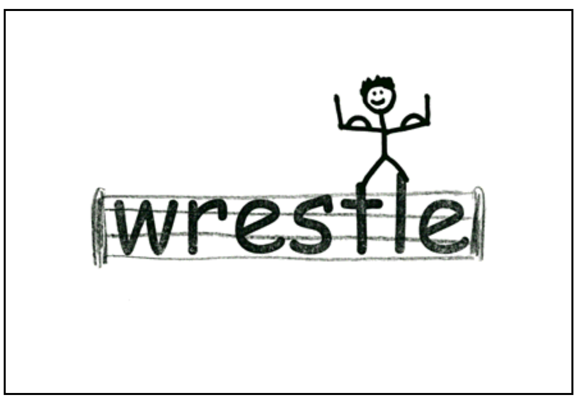
136) surges
137) igloo
138) mermaids
139) creaky
140) subscriber
141) shackles
142) ozone
143) banjos
144) lunchbox
145) commitment
146) tweezers
147) noodles
148) aspire
149) flirt
150) punctuality
151) option
152) cheeky
153) burglary
154) dumpling
155) cannibal
156) branch
157) cackle
158) tonsil
159) conservatory
160) vandal
161) ferret
162) meditate
163) appendix

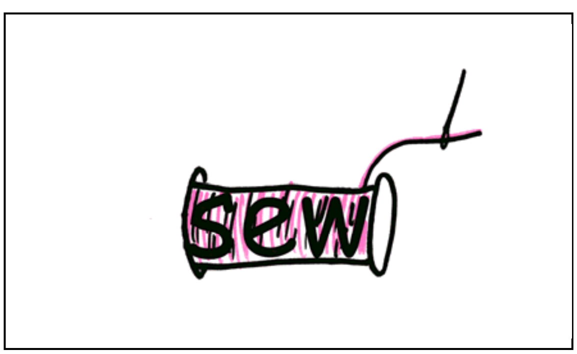
Appendix L: Visual Mnemonic Flashcards











Appendix M: GPC Sentences

(NB some GPCs are omitted as none of the children required them to be taught)

Target GPC Sentences

AI The frail maiden braided her hair as she watched the snail raid the bait in the hail.

AU The naughty girl felt daunted when the gaunt man at the laundry started to taunt her.

AY The crayfish strayed into the haystack looking for a tray of crayons.

A_E The tame lion raved in the crate as he felt shame after they shaved and scraped away his mane.

CH The charming man chattered to the chilled lady with a hunch while she chanted t the rabbit in the hutch.

CK The cricketer took his socks out of his locker and stacked the packets then he tickled the flock of sheep.

EA The bleating sheep pulled off his leash with a squeak then streaked over the peat with a gleam in his eye.

EE The sleek but feeble mouse peeped as he creeped down the man's sleeve to peek at the reef.

IE The priest grieved as his niece was a fiend and a thief and stole diesel.

I_E To dine on limes with my friend, I hike and glide over the stile which was covered with grime.

OA The bloated toad moaned and groaned but didn't need coaxing to take off his cloak and eat his toast.

OO The groovy groom hooted the horn on his scooter as the moose trooped over the hoop.

OW The sorrowful sparrow watched as the harrowed swallow stowed a marrow in the burrow.

O_E The pope arose from the dome, put on his robe and answered the phone then turned off the hose in the grove.

PH The pharmacist's nephew is good at physics, plays the saxophone, likes pheasants and dolphins and collects autographs.

QU The squawking quail squeezed out of the squeaky cage and quit after she quarrelled for being squirted.

TH He got a thrill on his seventh birthday when the snow thawed and a withered thrush saved a moth from a thorn.

U_E The cute girl was amused as she ate a prune when the mute computer fumed and sounded like a flute.

Appendix N: Phonological Generalisation Wordlists

1. Take
2. sweater
3. Soul
4. vost
5. happen
6. Shoe
7. Luck
8. salt
9. quock
10. prin
11. Sure
12. Pretty
13. breal
14. bond
15. chant
16. glow
17. Tomb
18. bick
19. trall
20. Delk
21. garage
22. ploat
23. common
24. sponge
25. plan
26. Pite
27. order
28. Work
29. Norf
30. napkin
31. talk
32. money
33. Crat
34. tough
35. Routine
36. modest
37. Mist
38. wune
39. bounce
40. Peril
41. Meringue
42. swobble
43. calf
44. machine
45. boop
46. coil
47. Lose
48. Blood
49. Weasel
50. Island
51. hope
52. Hest
53. Peng
54. Head
55. Gurve
56. said
57. Rint
58. grote
59. Yacht
60. Baft
61. trome
62. groat
63. chune
64. Wedding
65. peace
66. Grenty
67. naim
68. green
69. sign
70. Tapple
71. gaunch
72. Bouquet
73. spiral
74. mild
75. Boril
76. Spatch
77. blinty
78. Gauge
79. Need
80. Ganten
81. frine
82. billaw
83. nephew
84. Good
85. Friend
86. pitch
87. Pint
88. Free
89. Iron
90. Bleaner
91. Framp
92. Long
93. Break
94. food
95. Pofe
96. touch
97. Flannel
98. Peef
99. fist
100. stood
101. plint
102. Marsh
103. Stench
104. firm
105. Farl
106. brow
107. Eye
108. tield
109. each
110. trath
111. duel
112. Drop
113. Nerve
114. doot
115. Wolf
116. dance
117. Curb
118. spread
119. creesel
120. vring
121. Cord
122. smay
123. Come
124. come
125. phist
126. Colonel
127. Seldent
128. Chicken
129. Tail
130. vute
131. chaos
132. Middle
133. Chance
134. Life
135. Ceiling
136. buoy
137. Pump
138. Cough

139. build
140. Hand
141. Give
142. brood
143. subtle
144. mole
145. study
146. Brooch
147. gross
148. broad
149. Context
150. brist
151. Navy
152. Brinth
153. Doash
154. mipsen
155. Brennet
156. trope
157. Choir
158. reveal
159. Drick
160. Bowl
161. teeb
162. chimney
163. Borp
164. Check
165. tour
166. base
167. Plant
168. baby
169. note
170. Gop
171. aunt
172. repeat
173. Brandy
174. Aspy
175. Market
176. both
177. Stendle
178. ache
179. show
180. bed

Appendix O: Experiment 2: Phonological Training Programme – Spelling test

1. bant
2. bear
3. poath
4. rich
5. prane
6. beauty
7. hook
8. land
9. breapen
10. lang
11. swull
12. laugh
13. simple
14. wand
15. brump
16. letter
17. sister
18. libble
19. limb
20. shave
21. more
22. lost
23. butcher
24. circuit
25. lurf
26. made
27. branch
28. week
29. maunch
30. dough

Appendix P: Whole-word Generalisation Wordlists

1. acid
2. adopt
3. bield
4. bine
5. prumble
6. quife
7. biscuit
8. reep
9. scarrow
10. black
11. diesel
12. tribble
13. blinth
14. siren
15. bomb
16. sunten
17. bonil
18. prevent
19. walk
20. prite
21. war
22. buke
23. nurse
24. bull
25. trock
26. bury
27. cloam
28. clue
29. shove
30. cook
31. deaf
32. soil
33. tour
34. soup
35. death
36. winten
37. debt
38. dop
39. engine
40. farve
41. feet
42. goal
43. virth
44. five
45. boulder
46. fospy
47. frame
48. reldint
49. freight
50. frope
51. fulk
52. greal
53. group
54. sweat
55. grunnet
56. high
57. anchor
58. plug
59. answer
60. bant
61. bear
62. poath
63. rich
64. prane
65. beauty
66. hook
67. land
68. breapen
69. lang
70. swull
71. laugh
72. bruise
73. wand
74. brump
75. letter
76. sister
77. libble
78. limb
79. live
80. more
81. lost
82. butcher
83. circuit
84. lurf
85. made
86. branch
87. week
88. maunch
89. dough
90. sponge
91. dump
92. mayor
93. trang
94. music
95. name
96. once
97. parl
98. pest
99. jinty
100. lean
101. kind
102. know
103. lack
104. please
105. cane
106. chike
107. proof
108. quist
109. reason
110. reptile
111. ring
112. sand
113. seven
114. healthy
115. side
116. dwarf
117. simple
118. slate
119. leather
120. boot
121. broken
122. kind
123. slont
124. horse
125. jart
126. lady
127. snay
128. none
129. reetle
130. destiny
131. pipe
132. hain
133. pity
134. dift
135. nine
136. ocean
137. doof
138. text
139. define
140. half
141. despair

142. phurp
143. help
144. shave
145. pillow
146. thest
147. clenty
148. clinic
149. gaze
150. geyser
151. north
152. gloom
153. police
154. steak
155. ponder
156. possum
157. gone
158. troat
159. stome
160. trool
161. very
162. vock
163. wait
164. bottle
165. wild
166. minute
167. moof
168. least
169. sixteen
170. quitch
171. ready
172. wist
173. couple
174. crit
175. darp
176. wool
177. scarf
178. wute
179. zack
180. sat

Appendix Q: Experiment 2: Whole-word Training Programme – Spelling test

1. take
2. sweater
3. soul
4. vost
5. happen
6. shoe
7. luck
8. salt
9. quock
10. prin
11. sure
12. pretty
13. breal
14. bond
15. chant
16. glow
17. tomb
18. bick
19. trall
20. delk
21. garage
22. ploat
23. common
24. sponge
25. plan
26. pite
27. order
28. work
29. norf
30. napkin

Appendix R: Experiment 2 – Irregular Wordlist

1. through
2. warm
3. heart
4. weather
5. language
6. listen
7. measure
8. natural
9. strange
10. trouble
11. store
12. business
13. village
14. science
15. women
16. pretty
17. quiet
18. ancient
19. lady
20. believe
21. sugar
22. key
23. shore
24. bread
25. salt
26. touch
27. month
28. pushed
29. fruit
30. shoulder
31. breath
32. liquid
33. shook
34. usual
35. height
36. drew
37. broad
38. angle
39. rough
40. suit
41. tongue
42. pleasant
43. prove
44. quarter
45. character
46. foreign
47. thread
48. worry
49. worse
50. castle
51. stomach
52. blind
53. guard
54. canoe
55. washing
56. whistle
57. thumb
58. canal
59. wealth
60. rhyme
61. autumn
62. soup
63. flour
64. flood
65. muscle
66. hook
67. uniform
68. shone
69. feather
70. orchestra
71. cousin
72. oven
73. meadow
74. sword
75. mention
76. freight
77. medium
78. hind
79. honest
80. curtain
81. lamb
82. vegetable
83. shepherd
84. echo
85. worm
86. guitar
87. scheme
88. crude
89. comb
90. stalk
91. chorus
92. scissors
93. fried
94. vehicle
95. ballet
96. marine
97. diary
98. chalk
99. pirate
100. necklace
101. schedule
102. orchard
103. grind
104. sew
105. glove
106. seize
107. lettuce
108. pearl
109. ton
110. angel
111. villain
112. recipe
113. brow
114. giraffe
115. gym
116. awe
117. exhaust
118. virus
119. chemist
120. leopard
121. pear
122. coward
123. fury
124. dread
125. plague
126. barge
127. dove
128. hood
129. parachute
130. gown
131. budget
132. wasp
133. hymn
134. disguise
135. mechanic
136. senior
137. onion
138. thigh

139. mansion
140. trough
141. heir
142. super
143. eclipse
144. waltz
145. gem
146. sleigh
147. bandage
148. sausage
149. resign
150. bough
151. café
152. crook
153. soot
154. receipt
155. genie
156. tortoise
157. chore
158. honour
159. sieve
160. guilt
161. spinach
162. wrestle
163. pension
164. niece
165. gnome
166. mortgage
167. massage
168. camouflage
169. plumber
170. moustache
171. draught
172. xylophone
173. chauffeur
174. coupon
175. champagne
176. sardine
177. crumb
178. debut
179. beige
180. queue
181. beret
182. safari
183. cello
184. mural
185. suede
186. cleanse
187. chef
188. adore
189. typist
190. thyme
191. chasm
192. petite
193. puree
194. diaper
195. chaotic
196. mediterranean
197. lyrics
198. cymbal
199. plaits
200. quay

Appendix S: Experiment 2: Whole-word Training Programme sets of irregular words.

Block A: Visual Mnemonics

- Wordset 2
warm
business
key
liquid
pleasant
blind
soup
oven
vegetable
scissors
orchard
recipe
coward
wasp
super
crook
wrestle
xylophone
safari
petite

- Wordset 4
weather
science
bread
usual
quarter
canoe
flood
sword
echo
vehicle
sew
giraffe
dread
disguise
waltz
receipt
niece
coupon
mural
diaper

- Wordset 5
language
women
salt
height
character
washing
muscle
mention
worm
ballet
glove
gym
plague
mechanic
gem
genie
gnome
champagne
suede
chaotic

- Wordset 7
measure
quiet
month
broad
thread
thumb
uniform
medium
scheme
diary
lettuce
exhaust
dove
onion
bandage
chore
massage
crumb
chef
lyrics

- Wordset 9
strange
lady
fruit
rough
worse
wealth
feather
honest
comb
pirate
ton
chemist
parachute
mansion
resign
sieve
plumber
beige
typist
plaits

Block B: Degraded Images

- Wordset 1
through
store
sugar
breath
tongue
stomach
autumn
cousin
lamb
chorus
schedule
villain
pear
budget
heir
café
spinach
draught
beret
chasm

- Wordset 6
listen
pretty
touch
drew
foreign
whistle
hook
freight
guitar
marine
seize
awe
barge
senior
sleigh
tortoise
mortgage
sardine
cleanse
mediterranean

- Wordset 10
trouble
believe
shoulder
suit
castle
rhyme
orchestra
curtain
stalk
necklace
angel
leopard
gown
trough
bough
guilt
moustache
queue
thyme
quay

- Wordset 3
heart
village
shore
shook
prove
guard
flour
meadow
shepherd
fried
grind
brow
fury
hymn
eclipse
soot
pension
chauffeur
cello
puree

- Wordset 8
natural
ancient
pushed
angle
worry
canal
shone
hind
crude
chalk
pearl
virus
hood
thigh
sausage
honour
camouflage
debut
adore
cymbal

Appendix T: Experiment 2: Results for additional 'back-up' cases

As stated earlier, two further participants completed the Experiment 2 training programmes, in case of withdrawal by either of the target cases. The two additional cases were CP (a surface dyslexic) and TT2 (a phonological dyslexic). Their statistics and results are presented here, in a reduced format. CP partially met the criteria for surface dyslexia; although his IQ was below the required level, he attained a higher IQ score than the other potential surface dyslexic participant, so was included as a 'back-up' case. Of further limitation to CP's data was the ceiling effects he attained, particularly when reading regular words, and that his irregular word reading, which was originally very low, improved dramatically following completion of the Background Testing phase.

Pre-testing

General information, Pre-test and WISC-III IQ scores for the additional participants in Experiment 2.

Experiment 2	CP	TT2
Gender	M	M
Age (years, months)	11,1	11,08
Ethnicity	NZ Māori	NZ Māori
Reading subgroup	Surface	Phonological
Burt Reading Age	9,00-9,06	8,04-8,10
Coltheart & Leahy's (1996) wordlists[1]		
Regular words	29 N	22 A
Irregular words	16 B	19 N
Nonwords	22 N	10 A
WISC-III Full IQ	84	95
WISC-III Verbal IQ	88	92
WISC-III Performance IQ	83	100

On the further pre-tests, as with the key cases, no clear trends were evident according to dyslexia subtype, although CP scored slightly lower on many of the Visual subtests. On the Visual-Verbal and Verbal subtests, CP attained slightly higher scores on the ITPA subtests, particularly Sound Deletion.

Visual tests

Child	CP	TT2
Benton Visual Retention #correct (/10)	8	8
Expected score (/10)	5	6

[1] Note: Letters indicate reading band – A=Band A, indicates definite reading deficit, B=Band B, indicates borderline performance, N=Normal reading level for age group.

Benton Visual Retention - # error Expected score	2 7-8	5 6
Kaufman Gestalt (scaled)	7	10
Stanford Binet Bead memory (SAS)	49	55
ETS Identical Pictures (/96 max)	47	58
BORB Non-overlapping letters -Time (sec)	0.63	0.62
BORB Overlapping letters – Time difference cf. Non-overlapping letters (sec)	+0.44	+0.05
BORB Non-overlapping Pictures – (sec)	1.48	2.2
BORB Overlapping Pictures – Time difference cf. Non-overlap pictures (sec)	(-0.18)	+0.6
Visual No. Span (Max. length correct)	4	7
Auditory No. Span (Max. length correct)	6	6

Visual-verbal and verbal tests

	CP	TT2
Castles &Coltheart (1996) Homophone Matching:		
Regular target - Regular foil (e.g. bean/been) (/60)	44	49
Reg target –Irreg foil (e.g. 'fruit' - berry-bury) (/30)	23	22
Irreg target – Reg foil (e.g. 'song' – hymn-him) (/30)	26	25
Irregular target – Nonword foil (/30)	24	22
Illinois Tests of Psycholinguistic Abilities (2001):		
Sight Spelling (scaled)	8	7
Sound Spelling (scaled)	9	8
Sound Deletion (scaled)	10	7

In contrast to NS and WB, CP and TT2 completed the Whole-word Training Programme first, followed by the Phonological Training Programme. CP's and TT2's results are presented below, with data presented in tables, followed by statistical analyses for each child. Training Programme results are presented first, followed by Generalisation results from the Whole-word Generalisation Wordlists and Whole-word Generalisation Spelling test.

Whole-word Training Programme Results

Pre- and post-programme scores for correct reading of the trained irregular target words from the Experiment 2: Whole-word Training Programme. Results are presented for words trained using the Visual Mnemonics method (/100) and words trained using the Degraded Images method (/100), then overall scores (/200).

	CP		TT2	
	Pre	Post	Pre	Post
Visual Mnemonics	59	90	47	70
Degraded Images	61	92	37	77
Overall	120	182	84	148

- CP Whole-word Training Programme Results

Logistic regression analysis was conducted to investigate the impact of the variables of Testing Phase (Pre- or Post-Training Programme) and Technique used for Training (Degraded Images or Visual Mnemonics) on CP's reading score for the irregular words, and any interaction between these. CP's results indicated a significant improvement in his reading score of the trained irregular words following completion of the Training Programme, with Testing Phase having a significant main effect ($\chi^2(1)=58.24$, $p<0.001$). When the data was separated into words trained using the Degraded Images technique, and words trained using the Visual Mnemonics technique, both groups of data showed a significant improvement following training; Degraded Images ($\chi^2(1)=31.00$, $p<0.001$) and Visual Mnemonics ($\chi^2(1)=27.46$, $p<0.001$).

TT2 Whole-word Training Programme Results

Logistic regressions analysis for TT2's data for the Whole-word Training Programme revealed a significant main effect of Testing phase ($\chi^2(1)=53.83$, $p<0.001$) indicating TT2 significantly improved his reading of the trained irregular words following completion of the Training Programme. A significant interaction between the Testing Phase and the Technique used for training was also revealed ($\chi^2(1) =5.09$, $p<0.05$). TT2's scores indicate that the words trained using the Degraded Images increased by a greater extent than words trained using the Visual Mnemonics (words trained using Degraded Images improved from 37 to 77 correct; using Visual Mnemonics, from 47 to 70), indicating the Degraded Images technique was more effective for him. However, when both techniques were analysed separately, the main effect of Testing Phase was significant for both Degraded Images ($\chi^2(1) =36.36$, $p<0.001$) and Visual Mnemonics ($\chi^2(1) =17.06$, $p<0.001$), indicating significant improvements on both Techniques following the Training Programme.

Generalisation results are presented below, with scores from the Whole-word Generalisation Wordlists each out of a total of 60.

Scores for the Whole-word Generalisation Wordlists (out of 60), according to word subgroup, and Testing Phase (pre- and post-completion of the Experiment 2: Whole-word Training Programme). Scores for the Whole-word Generalisation Spelling test (out of 10).

	CP		TT2	
	Pre	Post	Pre	Post
Whole-wd Gen Wordlists (/60)				
Regular words	57	59	48	52
Irregular words	51	54	38	41
Nonwords	44	41	12	19

Whole-wd Gen Spelling test (/10)				
Regular words	7	6	5	4
Irregular words	6	7	5	7
Nonwords	5	7	2	1

- CP Whole-word Training Programme Generalisation Results

Logistic regression analysis was conducted on CP's scores for the Whole-word Generalisation Wordlists to investigate the main effects of Testing phase (Pre- or Post-Training Programme completion) and Wordtype (regular, irregular or nonwords). Results indicated a significant main effect of Wordtype ($\chi^2(2)=20.80$, $p<0.001$), but no significant effect of Testing Phase, indicating that CP did not significantly improve his overall score on the Whole-word Generalisation Wordlists following completion of the Whole-word Training Programme. When separated into regular, irregular and nonword Wordlists CP again showed no significant main effect of Testing Phase on any of the lists. It is of note that CP is no longer presenting with the attribute of surface dyslexia; difficulty with irregular word reading, compared to nonwords.

On the Whole-word Generalisation Spelling test CP attained slight increases in irregular and nonword scores and a slight decrease in regular words.

- TT2 Whole-word Training Programme Generalisation Results

TT2's data for the Whole-word Generalisation Wordlists were analysed using logistic regression and revealed significant main effects for Testing Phase ($\chi^2(1)=7.00$, $p<0.01$) and for Wordtype ($\chi^2(2)=48.96$, $p<0.001$). TT2's data indicate a significant difficulty with nonwords, as would be expected as he has phonological dyslexia. When the wordlists were analysed separately, no significant main effects of Testing Phase were found for any of the wordlists, indicating no significant generalisation following the Whole-word Training Programme.

On the Whole-word Generalisation Spelling test TT2 attained a 2-point improvement on his irregular words, from 5 to 7 out of 10 correct, but a 1-point decrease on both his regular and irregular words.

<u>Phonological Training Programme Results</u>

Pre- and post-programme scores for the Overall GPC Selection test scores (out of 200 – 5 regular word and 5 nonword examples for each of the 20 GPCs), Target GPCs (out of 100) and Nontarget GPCs (out of 100), each presented with percentage improvement.

	CP		TT2	
Overall GPC test Scores (/200)	Pre	Post (Improvement)	Pre	Post (Improvement)
- Overall	157	185 (18%)	106	167 (58%)
- Word	81	93 (15%)	58	90 (55%)
- Nonword	76	92 (21%)	48	77 (60%)

Target GPC Scores (/100)				
- Overall	65	86 (32%)	33	77 (133%)
- Word	35	43 (23%)	22	42 (91%)
- Nonword	30	43 (43%)	11	35 (218%)
Nontarget GPC Scores (/100)				
- Overall	92	99 (8%)	73	90 (23%)
- Word	46	50 (9%)	36	48 (33%)
- Nonword	46	49 (7%)	37	42 (14%)

CP Phonological Training Programme Results

It was not possible to perform logistic regressions to analyse CP's Phonological Training Programme data due to him attaining scores that neared ceiling. As a result, two-by-two chi-square analyses were conducted, employing Yates' Correction for Continuity. CP showed a highly significant improvements in his score on the GPC Selection test following the Phonological Training Programme ($\chi^2(1) = 14.70$, $p<0.001$). When the data was broken down into words and nonwords containing Target GPCs only, CP also made a significant improvement ($\chi^2(1)=10.812$, $p<0.001$). However, it was not possible to analyse solely the non-Target GPCs as this data neared ceiling and violated the chi-square assumption of the 'minimum expected cell frequency'. CP's data for the GPC Selection test was further analysed according to Wordtype; words and nonwords within the GPC Selection test. These chi-square analyses revealed significant improvements for both words only ($\chi^2(1) = 5.349$, $p<0.05$) and a slightly more significant improvement for nonwords only ($\chi^2(1) = 8.371$, $p<0.01$).

TT2 Phonological Training Programme Results

Analysis of TT2's overall results on the Phonological Training Programme revealed significant main effects of Testing Phase ($\chi^2(1)=51.95$, $p<0.001$), Target Status ($\chi^2(1)=27.82$, $p<0.001$) and Lexical Status ($\chi^2(1)=6.65$, $p<0.01$), with TT2's scores indicating greater accuracy for Target items, and for words, rather than nonwords. This was further confirmed with the analysis of the words and nonwords containing Target GPCs, which revealed significant main effects of Testing Phase ($\chi^2(1)=38.72$, $p<0.001$) and Lexical Status ($\chi^2(1)=6.61$, $p<0.01$). Analysis of the non-Target GPCs revealed a significant main effect of Testing Phase ($\chi^2(1) = 15.22$, $p<0.001$) and a significant interaction between Testing Phase and Lexical Status ($\chi^2(1) = 4.17$, $p<0.05$). TT2's scores indicate he improved significantly more on his nontarget words than nonwords following completion of the Phonological Training Programme.

Generalisation results are presented below, with scores from the Phonological Generalisation Wordlists each out of a total of 60.

Scores for the Phonological Generalisation Wordlists, according to subgroups of regular, irregular and nonwords, and Testing Phase (pre- and post-completion of the Experiment 2: Phonological Training Programme). Scores for the Phonological Generalisation Spelling test, comprising 10 regular words, 10 irregular words and 10 nonwords, selected from the Whole-word Generalisation wordlists.

	CP		TT2	
	Pre	Post	Pre	Post
Phonl Generalisn lists (/60)				
Regular words	55	57	42	48
Irregular words	44	44	36	41
Nonwords	39	50	14	30
Phonl Genralisn Spelling (/10)				
Regular words	10	10	9	9
Irregular words	6	6	3	3
Nonwords	5	8	2	6

CP Phonological Training Programme Generalisation Results
For the Phonological Generalisation Wordlists, logistic regressions revealed significant main effects of Testing Phase ($\chi^2(1) = 5.83$, $\underline{p} < 0.05$) and Wordtype ($\chi^2(2) = 17.09$, $\underline{p} < 0.001$) for CP's data. The interaction between Testing Phase and Wordtype neared, but did not reach significance ($\chi^2(2) = 5.30$, $\underline{p} = 0.071$). When the Wordtypes (regular, irregular and nonwords) were analysed separately, significant improvement was only found for the nonwords ($\chi^2(1) = 7.12$, $\underline{p} < 0.01$). This improvement indicates CP's generalisation of the sounding-out skills trained in the Phonological Training Programme to sounding out new untrained nonwords effectively. There was no change at all in CP's score for reading the irregular words, following completion of the Phonological Training Programme, resulting in a chi-square score of 0.

For the Phonological Generalisation Spelling test CP showed stable scores for the regular and irregular words, with a marked improvement from 5 up to 8 out of 10 correct for the nonwords.

TT2 Phonological Training Programme Generalisation Results
Logistic regression conducted on TT2's scores on the Phonological Generalisation Wordlists revealed significant main effects of Testing Phase ($\chi^2(1) = 14.22$, $\underline{p} < 0.001$) and Wordtype ($\chi^2(2) = 28.33$, $\underline{p} < 0.001$). Analysis according to Wordtype revealed a significant improvement in TT2's reading of nonwords only ($\chi^2(1) = 10.67$, $\underline{p} < 0.001$), not regular or irregular words. This indicates TT2 significantly generalised the 'sounding-out' skills he learned in the Phonological Training Programme.

TT2 showed stable scores for the regular and irregular wordsets on the Phonological Generalisation Spelling test but made a marked improvement from 2 up to 6 out of 10 for the nonwords.

Overall Reading Ability
CP's and TT2's reading ability was assessed with an initial Burt Word Analysis and Neale Analysis (Form 2) prior to beginning any training, Neale 2 (Form 1) following completion of their first training programme – the Whole-word Training programme, and a final readministration of the Burt Word Analysis and Neale 3 (Form 2) following completion of their second programme – the Phonological Training Programme. Results for each of these tests are presented below.

Burt Word Reading test and Neale Analysis scores before and after completion of training programmes, with Neale 2 administered between programmes. Chronological ages at time of test completion are presented in brackets. Neale scores provide Reading Age scores based on Accuracy.

	CP	TT2
Burt 1 – Pre Programmes -reading age	9.00-9.06 (11,01)	8.04-8.10 (11,08)
Burt 2 – Post Programmes -reading age	10.07-11.01 (11,04)	9.00-9.06 (12,0)
Neale 1 – Pre Programmes	8.07 (11.01)	7.07 (11.08)
Neale 2 – Between Progs	8.08 (11.02)	7.09 (11.10)
Neale 3 – Post Programmes	9.01 (11.04)	8.03 (12.0)

As results indicate, both CP and TT2 began the training intervention reading approximately two years behind their chronological age. Following completion of the Whole-word Training programme, both boys showed a very slight improvement of one to two months on the Neale. Following completion of their second programme, the Phonological Training programme, both boys further improved, to an overall improvement of six to eight months. On the Burt Word Analysis, both boys improved their reading age, with TT2 improving by eight months, and CP by 19 months. Some comments made by CP's and TT2's teachers include:

"Overall his confidence increased dramatically… in reading, writing and a willingness to share his ideas" (CP)

"(Increased ability in) sounding out words" (TT2)

"(A) genuine willingness to read that was not there before – i.e. went from silent reading comics and magazines to novels" (CP)

As the results indicate, both training programmes were significantly effective for both CP and TT2, in training the targetted words. It is of note, that TT2 showed higher improvement for the Phonological Training Programme than did CP and vice versa for the Whole-word Training Programme, supporting the hypothesis that participants would best respond to their target training programme. Within the Whole-word Training Programme, it is of note that TT2 showed significantly greater improvement with the Degraded Images technique compared to the Visual Mnemonics, suggesting further research into the effectiveness of this training technique would be of value. As with Experiment 1, no generalisation resulted from the Whole-word Training Programme for either participant, however significant generalisation to reading untrained nonwords resulted from the Phonological Training Programme for both CP and TT2. TT2. Further generalisation was evident in the improvement both participants made on their nonword spelling following completion of the Phonological Training Programme.

Table 1

Minimum and maximum scores, means and standard deviations of pretests for the 45 reading disabled children in Experiment 1.

	Scores			
Test	Min.	Max.	Mean	SD
Chronological age	7.08	13.07	12.09	1.29
Neale (reading ages)				
- Accuracy	6.09	13	8.30	1.66
- Comprehension	6.07	12.02	8.10	1.46
- Rate	6.09	13	8.44	1.77
Burt Word Reading Test (reading ages)	6.04	13.00	9.05	1.74
WISC-III Block Design (scaled scores)	4	16	10.84	2.40
Coltheart & Leahy wordlists (total correct)				
- Regular wds – total correct	8	30	24.07	4.82
- mean Band score[1]	1	3	1.82	0.86
- Irregular wds – total correct	9	25	18.73	3.39
- mean Band score	1	3	2.33	0.71
- Nonwords - total correct	0	28	14.25	7.63
- mean Band score	1	3	1.62	1.86

[1] Note: Letters indicate reading band – 1=Band A, indicates definite reading deficit, 2=Band B, indicates borderline performance
3=Normal reading level for age group

Table 2
General information regarding each participant completing Experiment 1
(Results for PS and MT presented in italics throughout, due to additional analyses)

	MJ	ST	PS	WC	MT	KI	GM	PJ	TT	LJ
Gender	F	F	*M*	F	*M*	M	F	M	M	M
Age (years, months)	13,1	12,2	*12,10*	9,4	*12,10*	12,2	12,6	12,9	12,2	13,0
Ethnicity	NZ Māori	Samoan	*Samoan*	NZ Euro	*NZ Euro*	Fijian Indian	NZ Euro	NZ Euro	NZ Euro	NZ Euro
Reading subgroup	Surface	Surface	*Surface*	Phonol	*Phonol*	Phonol	Phonol	Phonol	Phonol	Phonol
Burt Reading Age	8,08-9,02	9,08-10,02	*9,08-10,02*	6,11-7,05	*8,06-9,00*	8,01-8,07	7,07-8,01	8,01-8,07	9,08-10,02	9,03-9,09
Neale Analysis of Reading										
- Accuracy age	7.01	10.04	*8.05*	7.04	*7.10*	7.09	7.07	7.03	8.01	8.09
- Comprehension age	6.07	8.03	*7.05*	7.03	*8.03*	7.10	8.0	7.07	9.05	10.08
- Rate age	9.09	7.06	*8.08*	7.11	*10.02*	9.01	7.0	7.01	9.0	8.0
Coltheart & Leahy's (1996) wordlists[1]										
- Regular	27 B	27 N	*26 B*	20 B	*20 A*	23 A	18 A	21 A	29 N	26 B
- Irregular	18 B	18 B	*18 B*	14 B	*18 B*	17 B	19 N	16 B	21 N	22 N
- Nonwords	24 N	27 N	*27 N*	8 A	*1 A*	8 A	9 A	9 A	12 A	10 A
WISC-III Block Design	8	10	*16*	14	*13*	11	9	12	12	10

[1] Note: Letters indicate reading band – A=Band A, indicates definite reading deficit, B=Band B, indicates borderline performance
N=Normal reading level for age group

Table 3
WISC-III IQ scores for each participating child

Experiment 1	Surface Dyslexics			Phonological Dyslexics						
	MJ	ST	PS	WC	MT	KI	GM	PJ	TT	LJ
WISC-III Full IQ	65	69	*93*	103	*83*	85	87	98	91	90
WISC-III Verbal IQ	63	64	*80*	88	*76*	85	82	93	91	88
WISC-III Performance IQ	72	79	*111*	120	*106*	87	96	104	93	95

Table 4

Visual tests (Case study results for PS and MT presented in italics)

Experiment 1	Surface Dyslexics				Phonological Dyslexics				
Child	MJ	ST	PS	WC	MT	KI	GM	PJ	TT	LJ
Benton Visual Retention Test										
Number Correct (/10)	6	7	*9*	6	*8*	9	7	10	9	9
Expected score (/10)	5	4	*6*	4	*6*	6	6	7	6	7
Number Error	5	6	*1*	4	*2*	1	8	0	1	4
Expected score	8	9	*6*	9-10	*6*	6	6	5	6	5
Kaufman Gestalt (scaled)	8	7	*9*	14	*9*	10	14	12	9	13
Stanford Binet Bead memory (SAS)	43	39	*51*	60	*60*	49	55	57	60	47
ETS Identical Pictures (/96 max)	41	48	*62*	52	*50*	57	56	56	56	70
BORB subtests:										
Minimal Feature View (/25)	24	25	*25*	25	*25*	25	25	25	24	25
Non-overlapping letters -Time (sec)	0.45	0.50	*0.37*	0.58	*0.57*	0.47	0.80	0.72	0.65	0.45
Overlapping letters – Time difference cf. Non-overlap (sec)	+0.10	+0.12	*+0.10*	(-0.03)	*+0.04*	+0.30	+0.11	+0.10	+0.06	+0.12
Non-overlapping Pictures – (sec)	1.33	2.03	*0.93*	1.18	*1.00*	1.00	2.05	1.55	1.00	0.85
Overlapping Pictures – Time difference cf. Non-overlap (sec)	0	+0.30	*+0.32*	(-0.15)	*+0.05*	(-0.10)	+0.03	+0.43	+0.45	(-0.07)
Visual No. Span (Max. length correct)	6	5	*5*	5	*4*	6	5	5	6	6
Auditory No. Span (Max. length correct)	6	5	*5*	5	*0*	5	6	5	6	5

Table 5

Visual-verbal and Verbal tests

Experiment 1	Surface Dyslexics			Phonological Dyslexics						
	MJ	ST	PS	WC	MT	KI	GM	PJ	TT	LJ
Castles &Coltheart (1996) Homophone Matching:										
Reg target – Reg foil (e.g. bean/been) (/60)	47	56	*48*	46	*51*	50	47	43	55	49
Reg target –Irreg foil (e.g. berry-bury) (/30)	23	24	*25*	23	*23*	28	22	21	26	26
Irreg target – Reg foil (e.g. hymn-him) (/30)	25	23	*21*	23	*25*	25	24	22	28	22
Irregular target – Nonword foil (/30)	28	29	*23*	21	*26*	23	24	20	26	27
Olson Homophone Choice (/88)	66	80	*74*	76	*73*	77	77	77	75	76
Illinois Tests of Psycholinguistic Abilities (2001):										
Sound Decoding (scaled)	8	8	*9*	5	*3*	5	6	6	7	6
Sound Spelling (scaled)	10	10	*11*	10	*4*	4	8	8	11	7
Sight Decoding (scaled)	8	8	*8*	8	*7*	8	6	6	8	7
Sight Spelling (scaled)	9	8	*9*	8	*8*	8	9	5	8	8
Sound Deletion (scaled)	12	7	*13*	7	*6*	7	12	10	10	6
PALPA (1992) subtests:										
Word Minimal Pairs (/72)	71	70	*71*	69	*68*	64	71	71	70	68
Nonword Minimal Pairs (/72)	68	69	*67*	70	*67*	65	69	66	69	70
Nonword Repetition (/30)	29	28	*30*	28	*26*	27	30	29	30	29

Table 7
Mean scores and standard deviations for Coltheart & Leahy wordlists and the Alternative Wordlists. Results grouped for all dyslexics, then results for phonological and surface dyslexics presented separately.

Experiment 1		Phonological Training Programme Coltheart and Leahy wordlists				Whole-word Training Programme Alternative Wordlists			
		Pre		Post		Pre		Post	
		Mean	Std Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
All dyslexics	Reg words	25.80	2.86	26.80	2.74	26.50	3.10	27.40	1.84
	Irreg wds	21.10	1.60	20.60	2.27	21.20	2.86	23.90	2.47
	Nonwords	15.90	8.03	20.80	6.43	15.60	8.51	19.20	8.00
Surface dysl.	Reg words	28.33	0.58	28.67	1.53	29.67	0.58	29.33	1.16
	Irreg wds	20.33	2.52	20.67	2.89	23.00	1.73	26.00	1.00
	Nonwords	23.67	2.89	28.00	2.00	25.00	2.65	26.67	3.06
Phonol dysl.	Reg words	24.71	2.75	26.00	2.83	25.14	2.67	26.57	1.40
	Irreg wds	21.43	1.13	20.57	2.23	20.43	2.99	23.00	2.38
	Nonwords	12.57	7.14	17.71	4.86	11.57	6.58	16.00	7.23

Table 8

Burt Word Reading test and Neale Analysis scores before and after completion of training programmes. Chronological ages at time of test completion are presented in brackets. Neale scores provide Reading Age scores based on Accuracy. Order of Training Programmes – Phonological (p) and Whole-word (w) is noted next to child's name.

	Burt 1 - Pre	Burt 2 - Post	Neale 1 – Pre Progs	Neale 2 – mid-Progs	Neale 3 – Post Prog
Surface dysl					
MJ pw	9.05-9.11 (13.03)	10.11-11.05 (13.05)	9	8.02 (13.04)	9.03
ST wp	11.06-12 (12.04)	12-12.06 (12.07)	10.04	10.01 (12.06)	12.4
PS pw	*11.05-11.11 (13.0)*	*>13.03 (13.03)*	*8.07*	*9.11 (13.02)*	*9.10*
Phonl dysl					
WC pw	7.09-8.03 (10.01)	8.04-8.10 (10.04)	7.10	8.0 (10.03)	8.08
MT wp	*8.06-9 (13.0)*	*9.11-10.05 (13.03)*	*8.01*	*8.02 (13.01)*	*8.06*
KI wp	8.07-9.01 (12.04)	9.01-9.07 (12.07)	8.03	8.03 (12.06)	8.06
GM wp	8.-8.06 (12.09)	8.06-9 (13.0)	7.10	7.09 (12.11)	8.04
PJ pw	8.03-8.09 (12.11)	8.10-9.04 (13.02)	8.01	7.09 (13.01)	8.10
TT pw	10.11-11.05 (12.11)	N/A	9.03	8.01 (13.0)	9.01
LJ wp	10.04-10.10 (13.02)	11.01-11.07 (13.05)	9.01	9.01 (13.03)	9.03

Table 10

Pre- and post-programme scores for the Overall GPC Selection test (out of 200 – 5 regular word and 5 nonword examples for each of the 20 GPCs), and for the target GPCs (5 regular words and 5 nonword examples for each of the 10 target GPCs). Percentage Improvement (Imprv) given for each individual, along with group means and overall means. Order of Training Programmes – Phonological (p) and Whole-word (w) is noted next to child's name.

	Overall GPC Scores (/200)			Target GPC Scores (/100)			Non-target GPC Scores (/100)		
	Pre	Post	Imprv	Pre	Post	Imprv	Pre	Post	Imprv
Surface dysl									
MJ pw	163	191	17%	64	91	42%	99	100	1%
ST wp	180	190	6%	80	93	16%	100	97	-3%
PS pw	*166*	*183*	*10%*	*67*	*85*	*27%*	*99*	*98*	*-1%*
Surf Gp Mean	169.67	188	11%	70.33	89.67	28.33%	99.33	98.33	-1%
Phonl dyslexics									
WC pw	118	147	25%	34	68	100%	84	79	-6%
MT wp	*100*	*156*	*56%*	*33*	*72*	*117%*	*67*	*84*	*25%*
KI wp	126	157	25%	41	71	73%	85	86	1%
GM wp	139	179	29%	47	82	75%	92	97	5%
PJ pw	77	149	94%	24	65	175%	53	84	58%
TT pw	153	180	18%	60	88	47%	93	92	-1%
LJ wp	134	186	39%	49	91	86%	85	95	12%
Phonl Gp Mean	121	164.86	40.86%	41.14	76.71	96.14%	79.86	88.14	13.43%
Overall Mean	135.6	171.8		49.90	80.60		85.7	91.2	

Table 11
Scores for the Coltheart and Leahy (1996) wordlists, according to subgroups of regular, irregular and nonwords, and Testing Phase (pre- and post-completion of the Phonological Training Programme).

	Regular words		Irregular words		Nonwords	
	Pre	Post	Pre	Post	Pre	Post
Surface dysl						
MJ pw	28	27	20	19	22	26
ST wp	28	29	23	24	22	28
PS pw	*29*	*30*	*18*	*19*	*27*	*30*
Phonl dyslexics						
WC pw	23	22	21	17	11	15
MT wp	*24*	*25*	*23*	*22*	*1*	*9*
KI wp	23	26	22	22	12	17
GM wp	23	28	20	19	15	23
PJ pw	23	23	20	19	14	19
TT pw	30	29	22	23	25	23
LJ wp	27	29	22	22	10	18

Table 12

Mean reading times (in seconds) and standard deviations for correct responses on Coltheart and Leahy's (1996) wordlists, pre- and post-completion of the Phonological Training Programme. Differences between the pre- and post-programme times are presented for each individual, as well as group means for the surface and phonological dyslexics.

	Regular words			Irregular words			Nonwords		
	Pre	Post	Diffce	Pre	Post	Diffce	Pre	Post	Diffce
Surface dysl									
MJ pw	1.50 (0.47)	1.36 (0.97)	(-0.14)	1.43 (0.30)	1.14 (0.74)	(-0.29)	2.34 (0.88)	2.37 (1.49)	+0.03
ST wp	1.01 (0.26)	1.09 (0.60)	+0.08	1.31 (0.84)	1.40 (1.54)	+0.09	1.26 (0.76)	1.50 (0.88)	+0.24
PS pw	*1.06 (0.24)*	*1.05 (1.16)*	*(-0.01)*	*1.08 (0.35)*	*0.86 (0.21)*	*(-0.22)*	*1.51 (0.64)*	*1.03 (0.37)*	*(-0.48)*
Surf gp mean			(-0.02)			(-0.14)			(-0.07)
Phonl dysl									
WC pw	1.21 (0.47)	1.36 (1.30)	+0.15	1.38 (0.68)	2.13 (2.04)	+0.75	3.91 (1.67)	4.37 (3.12)	+0.46
MT wp	*0.99 (0.44)*	*1.43 (1.04)*	*+0.44*	*0.85 (0.34)*	*1.30 (0.78)*	*+0.45*	*0.90*	*1.77*	*+0.87*
KI wp	1.44 (1.27)	1.22 (0.71)	(-0.22)	1.18 (0.61)	1.37 (0.95)	+0.19	2.32 (0.85)	3.07 (2.33)	+0.75
GM wp	1.64 (0.95)	1.99 (1.77)	+0.35	1.68 (1.30)	1.67 (1.59)	(-0.01)	2.98 (1.54)	2.89 (2.10)	(-0.09)
PJ pw	1.75 (0.74)	1.76 (1.31)	+0.01	1.76 (0.68)	1.87 (0.96)	+0.11	3.38 (1.54)	3.96 (2.09)	+0.58
TT pw	1.14 (0.37)	0.93 (0.38)	+0.21	1.09 (0.51)	0.90 (0.26)	(-0.19)	1.79 (0.53)	1.62 (0.54)	(-0.17)
LJ wp	0.97 (0.62)	0.94 (0.40)	(-0.03)	0.76 (0.29)	0.94 (0.62)	+0.18	1.16 (0.41)	1.09 (0.40)	(-0.07)
Phonl gp mean			+0.13			+0.21			+0.33

Table 13
Pre- and post-programme scores (/50) for correct reading of the trained irregular and regular target words in the Whole-word Training Programme, with reading times and standard deviations (for correctly read words only). Order of Training Programmes – Phonological (p) and Whole-word (w) is noted next to child's name.

	Overall		Regular words				Irregular words			
	Score		Score		Time (sec)		Score		Time (sec)	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Surface dysl										
MJ pw	31	99	25	49	2.27 (2.00)	0.93 (0.43)	6	50	2.54 (2.32)	1.04 (0.27)
ST wp	42	99	32	49	1.53 (1.09)	0.87 (0.26)	10	50	1.95 (1.58)	0.89 (0.19)
PS pw	*43*	*99*	*29*	*50*	*1.34 (0.80)*	*0.89 (0.19)*	*14*	*49*	*1.24 (0.64)*	*0.84 (0.24)*
Phonl dysl										
WC pw	24	100	14	50	2.29 (1.67)	0.97 (0.48)	10	50	2.82 (2.88)	0.98 (0.34)
MT wp	*43*	*100*	*24*	*50*	*1.70 (1.54)*	*0.89 (0.33)*	*19*	*50*	*2.31 (2.75)*	*1.10 (0.47)*
KI wp	49	96	22	48	1.52 (1.24)	1.24 (0.89)	27	48	2.08 (1.50)	1.34 (0.86)
GM wp	49	95	34	49	1.72 (1.06)	1.23 (0.49)	15	46	2.80 (1.65)	1.10 (0.19)
PJ pw	19	95	11	48	2.30 (1.26)	1.56 (0.94)	8	47	3.15 (1.68)	1.58 (0.86)
TT pw	42	100	27	50	1.77 (0.99)	0.82 (0.20)	15	50	1.61 (0.78)	0.99 (0.33)
LJ wp	55	97	27	48	1.35 (0.98)	0.63 (0.19)	28	49	1.93 (1.36)	0.73 (0.21)

Table 14

Scores for the Alternative Wordlists, according to word subgroup, and Testing Phase (pre- and post-completion of the Whole-word Training Programme). Order of Training Programmes – Phonological (p) and Whole-word (w) is noted next to child's name.

	Regular words		Irregular words		Nonwords	
	Pre	Post	Pre	Post	Pre	Post
Surface dysl						
MJ pw	29	28	22	26	24	26
ST wp	30	30	25	27	23	24
PS pw	*30*	*30*	*22*	*25*	*28*	*30*
Phonl dyslexics						
WC pw	25	27	15	21	8	15
MT wp	*25*	*25*	*23*	*25*	*3*	*4*
KI wp	25	25	20	23	8	10
GM wp	25	27	20	23	12	20
PJ pw	20	27	19	19	14	20
TT pw	28	29	24	26	24	26
LJ wp	28	26	22	24	12	17

Table 15

Mean reading times and standard deviations for correct responses to the Alternative Wordlists, according to word subgroup, and Testing Phase (pre- and post-completion of the Surface Reading Programme).

	Regular words			Irregular words			Nonwords		
	Pre	Post	Diffce	Pre	Post	Diffce	Pre	Post	Diffce
Surface dysl									
MJ pw	1.11 (0.68)	1.07 (0.48)	(-0.04)	1.62 (1.55)	1.47 (0.91)	(-0.15)	2.25 (1.20)	1.65 (0.90)	(-0.60)
ST wp	N/A	1.05 (1.04)		N/A	0.94 (0.42)		N/A	1.92 (2.09)	
PS pw	*1.14 (0.85)*	*0.95 (0.63)*	*(-0.19)*	*1.16 (0.74)*	*0.94 (0.48)*	*(-0.22)*	*1.11 (0.70)*	*0.99 (0.42)*	*(-0.12)*
Surf gp mean			(-0.12)			(-0.19)			(-0.36)
Phonl dysl									
WC pw	1.17 (0.91)	1.25 (0.83)	+0.08	1.21 (0.55)	1.31 (0.83)	+0.10	2.25 (2.01)	1.65 (1.01)	(-0.60)
MT wp	*1.05 (0.43)*	*1.09 (0.51)*	*+0.04*	*1.22 (0.86)*	*1.21 (0.89)*	*(-0.01)*	*N/A*	*N/A*	
KI wp	1.35 (0.49)	1.05 (0.46)	(-0.30)	1.35 (0.68)	1.15 (0.42)	(-0.20)	1.15 (0.42)	2.14 (1.49)	+0.99
GM wp	2.39 (4.03)	1.00 (0.33)	(-1.39)	1.51 (1.16)	0.99 (0.34)	(-0.52)	2.33 (1.67)	1.59 (0.96)	(-0.74)
PJ pw	2.07 (1.32)	2.02 (1.31)	(-0.05)	1.96 (1.47)	2.50 (1.97)	+0.54	3.46 (1.53)	3.57 (1.22)	+0.11
TT pw	1.18 (0.63)	1.13 (0.60)	(-0.05)	0.95 (0.40)	1.08 (0.60)	+0.13	1.65 (1.09)	1.70 (0.79)	+0.05
LJ wp	0.98 (0.36)	0.96 (0.68)	(-0.02)	1.02 (0.46)	0.84 (0.38)	(-0.18)	1.57 (0.68)	1.52 (0.73)	(-0.05)
Phonl gp mean			(-0.24)			(-0.02)			(-0.03)

NB Due to technical difficulties, the reading times were not available for ST's pre-programme data. MT did not read any of the nonwords correctly on both the pre- and post-tests, therefore reading times can not be assessed for MT's nonwords.

Table 18
Minimum and maximum scores, means and standard deviations of pretests for the 49 reading disabled children assessed in Experiment 2.

	Scores			
Test	Min.	Max.	Mean	SD
Chronological age	10.0	12.11	11.08	0.72
Burt Word Reading Test (reading ages)	6.0	14.0	9.09	1.91
WISC-III Block Design (scaled scores)	3	14	10.22	2.48
Coltheart & Leahy wordlists (total correct)				
- Regular wds	19	30	26.66	3.23
- Irregular wds	9	25	19.85	2.89
- Nonwords	3	29	19.09	6.92