INDIVIDUAL DIFFERENCES IN DYSLEXIA

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ABSTRACT

The current research attempted to understand individual differences in dyslexia by investigating potential sex differences (behavioural, cognitive and remedial), subtypes and predictors of symptom severity.

The results did not specifically support the hypothesis that behavioural factors were related to the increased number of male dyslexics reported in the literature. Cognitive sex differences were identified on the months forwards subtest of the Bangor Dyslexia Test and on the digit span, coding and symbol search subtests from WAIS-III^{UK}. In all cases, females outperformed males. Although the ACID, AVID and SCAD profiles were not found to characterise the performance of either sex, performance on the ACID, AVID and SCAD factor scores appeared more related to dyslexia in males. The findings indicated that sex differences may affect the manifestation of dyslexia related problems. Male and female dyslexics did not differ with regard to the level, rate or endurance of improvement following different methods of spelling instruction. Rather than sex, reading ability was found to predict spelling improvement following intervention.

The adult dyslexics studied continued to show deficits on a range of tasks usually used to assess dyslexia in children. Although it was possible to divide the adult dyslexics into phonological and surface subtypes, subsequent analyses designed to assess the utility of this classification system suggested that the validity of the subtypes was questionable. Similar measures were found to predict the reading ability of dyslexic and non-dyslexic adults. However, the groups differed with regard to predictors of spelling and reading comprehension ability. Severity differences in one or several underlying core deficits were considered a more meaningful way of accounting for individual differences in dyslexia than the existence of distinct subtypes.

ACKNOWLEDGEMENTS

CONTENTS

3. INDIVIDUAL DIFFERENCES IN ADULT DYSLEXICS

4. DISCUSSION

APPENDICES

1. INDIVIDUAL DIFFERENCES IN DYSLEXIA

1.1 Synopsis

Dyslexia is usually defined on the basis of a collection of observable behaviours or symptoms. Although most definitions (e.g. World Federation of Neurology, 1968; British Dyslexia Association, 2000; British Psychology Society, 1999) include difficulties with literacy acquisition (e.g. learning to read and spell) a varied collection of additional deficits are also frequently described. These difficulties include problems processing information (particularly at speed), problems with working memory or short term memory, problems with phonological processing, sequencing, numeracy, motor skills, spoken language and visual and auditory processing. The extent to which a single dyslexic experiences any or all of the aforementioned weaknesses varies considerably.

Dyslexia is a multivariate disorder, characterised by a diverse set of symptoms, which appear to differ from one dyslexic to the next. The current research attempts to reduce these individual differences, by identifying subgroups of dyslexics that vary in consistent ways. The possibility that dyslexic symptoms vary as a function of sex differences or subtype of dyslexia is investigated, as are the underlying skills that could potentially predict variability in the severity of dyslexic symptoms. Understanding individual differences has practical implications in terms of diagnosis and remediation as well as theoretical implications. Rispens et al (1994) maintained that heterogeneity represents an "important problem that has to be resolved in order to enhance the clinical relevance of the concept of dyslexia" (page 72).

Following a brief introduction to dyslexia, several causal models are described. The Phonological Deficit Hypothesis was considered as phonological deficits are acknowledged by both unitary and multiple causation theories (described in section 1.6). The Temporal Processing Hypothesis and the Cerebellar Deficit Hypothesis were considered as visual, and to a lesser extent motor, deficits characterise the non-linguistic subtype of dyslexia that distinguishes unitary and multiple causation theories. These hypotheses are described within the framework proposed by Frith (1997). This framework links neurological or biological impairments with cognitive

1

deficits and ultimately overt behaviour. At a biological level, individual differences could result from varying degrees of impairment in a single underlying brain dysfunction, from different neurological impairments or from correlated dysfunctions in different brain regions. Similar arguments can be made at the cognitive level. Differences in the behavioural manifestation of dyslexia could result from a single cognitive deficit that varies in severity, or from a variety of processing deficits that either co-occur or exist in isolation.

The first possibility describes dyslexia as a unitary construct (e.g. resulting from a single neurological or cognitive deficit). In this instance, individual differences reflect different positions on a continuous scale that varies from good to poor. Dyslexic symptoms differ according to the degree of cognitive or biological impairment. The remaining possibilities suggest the existence of qualitatively different types of dyslexia. For example, independent neurological impairments that result in different processing deficits could cause different subtypes of dyslexia. Alternatively, correlated brain dysfunctions could result in a variety of processing deficits that combine differentially at an individual level. In Chapter 3, data are presented that assess these possibilities by attempting to divide a sample of adult dyslexics into subtypes. The efficiency of the subtyping procedure is considered, as are potential predictors of symptom severity.

The extent to which biological deficits manifest at the cognitive level depends on what Frith (1997) described as 'protective' or 'risk' factors. One such factor examined within the current research was sex differences. This was considered of pertinence to dyslexia which has a reported male to female ratio of four to one. It was hypothesised that innate cognitive sex differences (reviewed in Chapter 2) could affect the manifestation of dyslexic symptoms, thus contributing to the diversity observed within dyslexic samples. The possibility that dyslexia is qualitatively (i.e. characterised by different cognitive deficits) and/or quantitatively (i.e. varies in term of severity) different between the sexes is investigated by examining the performance of males and females on various measures typically used to assess dyslexia. The extent to which behavioural differences between the sexes contributed to the

increased incidence of dyslexia in males was also investigated, as was the differential effectiveness of different remediation procedures.

1.2 Introduction

The term dyslexia originated from the Latin/Greek phrase meaning 'a difficulty with words'. It exists in both an acquired and developmental form, although the term was initially used to refer to acquired dyslexia (Berlin, 1872, cited in Thomson, 1990) as an alternative to Alexia or 'word blindness' (Kussmaul 1877, cited in Thomson, 1990). Acquired dyslexia is a neurological condition resulting in literacy-related difficulties following injuries to the brain; for example, strokes, tumours or traumatic injuries. Developmental dyslexia describes individuals who experience problems with the initial acquisition of literacy skills. The lack of evidence pertaining to an associated brain injury suggests that individuals are born with the condition, possibly due to some kind of genetic influence (see recent reviews by DeFries, Alarcon and Olson, 1997; Fisher and Smith, 2001).

The first description of individuals who experienced unexpected reading problems in the absence of specific neurological damage appeared in Eugene Labiche's La Grammaire (1867) (Galaburda, 1985). This was followed by the accounts of W. Pringle Morgan in 1896, James Kerr in 1897 and James Hinshelwood in 1917 (cited in Thomson, 1990). James Hinshelwood (1917) was the first to describe developmental reading difficulties within the context of current neurological understanding in his book 'Congenital word-blindness'. Hinshelwood perceived congenital word blindness (what we now understand to be dyslexia) as a problem with brain development, specifically a "failure to develop the brain function associated with visual memory of words, letters or figures" (Thomson, 1990, page 4).

In the US, Orton (1925, 1937, cited in Thomson, 1990) noted the increased frequency of transposal, inversion and reversal errors made by dyslexics, which he attributed to the way memory engrams were represented within the two hemispheres of the brain. Orton postulated that in 'normal' brains the dominant hemisphere (e.g. the left for language) represented images or words in the correct orientation, whilst

the other hemisphere (e.g. the right) displayed the reversed or mirrored form. Orton argued that these images were allowed to compete in the dyslexic whose cerebral dominance was poorly established. Orton referred to this condition as strephosymbolia (meaning twisted signs) or developmental alexia.

These early descriptive definitions viewed dyslexia as a medical syndrome diagnosed through the identification of characteristic features or symptoms. Although some professionals within the field continued to work within this framework (e.g. Miles, 1993), the 1970s witnessed a shift in emphasis that focused predominantly on reading ability and its relationship with intelligence. The 'educational viewpoint', described by Snowling (1996), maintained that "children who have unexpected difficulty in learning to read should be identified on these grounds alone" (page 5). The use of a discrepancy model was adopted following the Government Green Paper or Tizard Report (1972, cited in Thomson, 2001).

The Tizard Report was derived from the findings of Rutter, Tizard and Whitmore (1970) whose epidemiological data from the Isle of Wight was used to examine the relationship between reading and intelligence. These authors and others (Berger et al, 1975; Yule, 1967; Yule, 1973; Yule et al, 1974) used regression equations based on the correlation between reading and IQ to predict expected reading ability at varying levels of intelligence. This regression based discrepancy model demonstrated the distinction between general learning difficulties and specific reading difficulties. For example, a child whose reading ability was below chronological age but in line with intelligence was considered 'backward' (Thomson 1990, page 6), whereas a child whose reading was significantly below (e.g. two standard deviations) the reading level predicted by their intellectual ability was regarded as specifically retarded in reading.

Descriptions of children with general learning and specific reading difficulties alluded to qualitative and statistical distinctions between the two conditions. At a qualitative level, children with general learning difficulties were regarded as slow learners, delayed in terms of their general development and educational attainment. Their difficulties were viewed as more likely to be associated with their social status

4

or organic neurological dysfunctions. Individuals with specific reading retardation, however, had enduring (e.g. resistant to remediation) difficulties, predominantly with reading and spelling. These early studies also reported an increased incidence of males within samples of children with specific reading difficulties (Rutter, Tizard and Whitmore, 1970).

Statistical differences pertained to the somewhat contested (Rodgers, 1983; Wessel and Zegers, 1985) distribution of discrepancy scores (e.g. the number of individuals whose actual reading was two standard deviations below their expected reading). Slow learners were seen to represent the bottom end of the normal distribution, whilst individuals with specific reading retardation constituted an anomalous population that deviated from normality, resulting in a 'hump' at the lower end of the normal distribution curve.

Prior to the Tizard Report, under the 1944 Education Act which did not recognise dyslexia, a child with dyslexic difficulties would receive support only if they were labelled 'educationally sub-normal' or 'maladjusted'. Thomson (2001) accredits the Tizard Report as the "first official recognition that there were children who had specific difficulties [and maintained that it] laid the foundation for an acceptance of dyslexia as a learning problem" (page 8). However, it should be noted that the Tizard Report did not advocate the use of the term 'dyslexia', referring instead to 'specific reading difficulty', a condition that was not perceived as warranting specialist assessment or remediation. Similarly, the Bullock Report (1975, cited in Thomson, 1990) referred to 'specific reading retardation'. It was not until some of the recommendations of the Warnock Report (1978, cited in Thomson, 1990) were incorporated in the Special Educational Needs Act of 1981 and subsequent acts in 1983 and 1994 that support for dyslexics became more readily accessible. The 1981Act provided provisions for individuals who manifested significant learning difficulties relative to their peers that interfered with their ability to access the curriculum. This included children with specific learning difficulties.

The early discrepancy models established the conceptual distinction between different groups of poor readers and introduced the concept of specific reading

retardation or specific learning difficulties. However, specific reading retardation can be caused by numerous factors and was perceived by Snowling (1996, page 10) as far to 'over-inclusive' to be used synonymously with dyslexia. Similarly, Miles et al (1998) argued that "defining dyslexia as poor reading in relation to intelligence was not so much wrong as incomplete" (page 32) – maintaining that children can be poor readers for a number of different reasons. For example, motivational or emotional factors, lack of appropriate teaching, extended school absences and language difficulties. The term specific reading retardation also ignores the other literacy (e.g. spelling) and cognitive deficits that represent defining characteristics of dyslexia.

Early theories pertaining to the aetiology of dyslexia focused on perceptual deficits (e.g. deficits within the initial stages of visual and auditory information processing). For example, the seemingly visual difficulties noted by Orton (1925, 1937) fuelled research into the possible causal role of visual perceptual, visual spatial/directional and visual-motor deficits in dyslexia. However, by the late 1970s difficulties within these areas were largely attributed to intellectual, memory or verbal labelling deficits rather than specific visual weaknesses (Thomson, 1990). Similarly, in the 1960s and 70s the relationship between auditory perception and literacy skills was investigated and dyslexics were found to perform poorly on auditory discrimination tasks. However, when the different aspects of speech perception were investigated, phonological processing (e.g. phoneme segmentation and synthesis), rather than the initial sensory analysis, was determined to be problematic for dyslexics. According to Snowling et al (1986) these phonological speech perception deficits interfered with the dyslexic's ability to establish phonological representations of words encountered in speech.

The culmination of many years of research into dyslexics' memory and sequencing difficulties has reached very similar conclusions. The well established deficits on span and serial (e.g. sequential or temporal) memory tasks are now believed to be manifestations of verbal or phonological coding deficits within working memory. Working memory is generally perceived as a tripartite system consisting of the central executive, phonological loop and visuospatial sketchpad. Rather than a general working memory capacity constraint, a problem with long term memory or a

specific sequencing deficit, a dysfunction within the phonological loop is generally believed to be associated with dyslexia. The phonological loop is divided into the articulatory control system, which rehearses verbal material and is sensitive to sequential or temporal order, and the phonological store. The ability to create enduring representations of novel speech is mediated by the phonological loop, which is responsible for the coding and temporary storage of phonological information whilst a representation is established in long term memory. The Working Memory Hypothesis of dyslexia described by the Working Party of the Division of Educational and Child Psychology (1999) depicts cognitive memory deficits as either directly resulting from biological brain differences or as a consequence of a phonological processing deficit. The latter suggests that overt memory deficits are the result of an underlying phonological deficit. Although Frith (1997) maintained that the relationship between these problems remains unclear (e.g. whether they are separate deficits or different aspects of a single deficit), Thomson (2001) argued that there was "not much distinction between the phonological loop in working memory and phonological deficits [and that] these seem to be all part of the same weak process in people with dyslexia" (page 129).

1.3 The Phonological Deficit Hypothesis

These early studies appeared to indicate that rather than sensory perception, memory or sequencing problems, dyslexia was the result of a verbal or phonological processing deficit. At a biological level, PET scans revealed abnormal neural activity within the phonological system located in the perisylvian region of the left hemisphere (Paulesu et al, 1996; Galaburda, 1989; Rumsey et al. 1992). This system, consisting of Broca's area, Wernicke's area, the insula and the inferior parietal lobule, appeared disconnected in dyslexics compared to controls when performing phonological tasks (Paulesu et al, 1996). It is conceivable that these genetically determined brain differences could manifest at the cognitive level. Frith (1997) highlights the 'probabilistic' rather than 'deterministic' nature of this relationship due to the influence of cognitive 'protective' or 'risk factors'. The possibility exists that innate cognitive sex differences could function in this capacity. Research reviewed in Chapter 2 suggests that females demonstrate superior abilities on those

7

aspects of cognition and literacy on which dyslexics consistently show deficits. This relative superiority could represent a 'protective' factor inherent within females that either prevents or alters the expression of dyslexia at the cognitive and ultimately behavioural level. Alternatively, the relative verbal weaknesses within the typically masculine cognitive profile could represent a 'risk' factor predisposing to dyslexia. This would be consistent with the findings that dyslexia is a predominantly male condition. According to Frith (1997) "even with the same phonological disorder one individual may adjust well and find ways of learning through different means; another may not cope well and may need constant support" (page 16). Girls in general are viewed by their teachers as more tolerant, adaptive and better able to compensate for their difficulties.

Within most models (even those that implicate brain regions not specifically concerned with phonological processing), a phonological deficit is considered to be the cognitive basis of dyslexia. The Phonological Representations/Deficit Hypothesis or the Phonological Model of Dyslexia suggests that dyslexics experience problems with the representation of phonological information within the language processing system. For example, several authors (Snowling and Nation, 1997; Shaywitz,1996; Elbro, Borstrom and Petersen, 1998) refer to the quality or distinctiveness of phonological representations, maintaining that poorly established representations of speech sounds could account for the array of difficulties experienced by dyslexics (e.g. difficulties on phonological and naming tasks).

A wealth of empirical data exists that supports the predictions of the phonological deficit hypothesis. For example, numerous studies have determined that children genetically predisposed to dyslexia (i.e children with a dyslexic parent or parents) show 'linguistic disturbances' (Scarborough, 1990) evident by eight months of age that distinguish them from control children (Locke et al, 1997). These linguistic disturbances included poor phonological awareness during pre-school which predicted subsequent reading ability (Bradley and Bryant, 1983; Lundberg, Frost and Peterson, 1988; Lundberg, Olofsson and Wall, 1980).

The relationship between poor phonological skills and difficulties with literacy acquisition is described by Lundberg and Hoien (2001) as "one of the most robust findings in developmental cognitive psychology" (page 112). These authors interpreted the predictive relationship between poor phonological awareness and reading failure within a causal framework, describing phonological awareness as a mechanism that "lies at the very heart of the process of learning to read" (page 120). It should be noted, however, that this relationship is interactive and bidirectional, at least in 'normal' readers. The acquisition of word recognition skills is dependent on an inherent awareness of sounds; however, the process of learning to read and spell an alphabetic script improves phonological awareness which in turn facilitates further advances in literacy. Nonetheless, poor phonological skills make learning to read and write incredibly difficult (Rack et al, 1992), and numerous researchers have recognised the beneficial effects of phonological training programmes on reading attainment (Bradley and Bryant, 1983; Hatcher, Hulme and Ellis, 1994; Lundberg, Frost and Petersen, 1988).

As previously mentioned most models of dyslexia describe phonological deficits at the cognitive level, however the biological origins of these deficits vary from theory to theory. In addition to differences within the brain's phonological system, magnocellular and cerebellar impairments have also been related causally to dyslexia.

1.4 The Temporal Processing Hypothesis

Although the idea that dyslexic difficulties included some form of visual perceptual deficit was largely discarded in the late 1970s, subsequent research suggests that visual processing problems may, after all be contributing to reading impairments (Watson and Willows, 1993). There are two hypothesised interacting systems that sub-serve visual processing, the magnocellular or transient system and the parvocellular or sustained system. The magnocellular system is concerned with the processing of movement or rapidly occurring events, providing only course, poorly defined information pertaining to global shapes and position. The parvocellular system conversely samples high resolution spatial detail at a more sustained and

slower rate. Research suggests that differences between normal and disabled readers are specific to magnocellular processing, with differences under sustained processing conditions proving either non existent or minor in comparison (Lovegrove and Williams, 1993).

The impact of a magnocellular deficit on the reading process is thought to stem from this systems control of the eye movements in-between fixation intervals (saccadic eye movements) and the maintenance of stable visual perception during fixations. Stein and Walsh (1997) described how a magnocellular deficit might disrupt the normal ability of the posterior parietal cortex (region of the visual cortex to which magnocellular geniculate cells extend) to control eye movements and contribute to the visual perceptual difficulties experienced by dyslexics (e.g. binocular instability or unstable vergence control). According to Stein et al (2001), a magnocellular deficit could result in unstable visual perception which interferes with the ability to extract and process orthographic detail (e.g. letter order) from text. Both lexical and sublexical reading routes (described in Chapter 3) rely on the preliminary visual analysis of text; a magnocellular deficit could therefore affect both mechanisms. However, visual processing problems are deemed more likely to interfere with lexical or orthographic mechanisms which are not supported by phonological processing. According to Snowling and Nation (1997) a subtype of dyslexia (surface dyslexia) characterised by problems with lexical mechanisms could potentially result from visual deficits. In support of this hypothesis, Talcott et al (2000) found visual motion sensitivity (a process controlled by the magnocellular system) to be positively correlated with orthographic processing ability.

Magnocellular deficits have also been argued to co-occur with phonological processing problems (Slaghuis et al, 1993). Indeed the magnocellular deficit theory has recently been extended to included deficits in auditory processing. Stein and Walsh (1997) suggested that dyslexic's phonological processing difficulties could result from an "impairment in low-level auditory transient processing, which is analogous to their visual magnocellular defect" (page 151). Stein and Walsh (1997) referred to auditory pathways consisting of hypothesised auditory magnocells, and cited evidence of an associated abnormality in dyslexia (Galaburda, Menard and

Rosen, 1994). These pathways were found to be involved in auditory temporal processing, including sensitivity to changes in frequency and amplitude that distinguish letter sounds (phonemes) at an acoustic level. According to Stein et al (2001), poor readers were worse at detecting both frequency and amplitude modulations, with the sensitivity to such changes being positively correlated with phonological processing ability.

The temporal processing hypothesis (generalised magnocellular hypothesis) posits that dyslexic difficulties ensue temporal processing deficits that extend across visual, auditory and motor domains. For example, a temporal processing or general timing deficit could, according to Stein and Walsh (1997), explain the motor deficits or 'soft cerebellar signs' often exhibited by dyslexics.

1.5 The Cerebellar Deficit Hypothesis

The cerebellar deficit hypothesis described by Nicolson and Fawcett (1999) represents another (although potentially related) causal theory of dyslexia that attempts to link neurological or biological impairments with cognitive deficits and ultimately overt behaviour. According to this perspective, a mild cerebellar impairment is causally related to dyslexia. The cerebellum is a subcortical brain structure involved in the co-ordination of movement. Although typically perceived as a motor area, it has evolved considerably in humans and is believed to play a role in the learning and automatization of cognitive and linguistic skills as well as motor skills (Leiner, Leiner and Dow, 1989, 1993).

Fawcett, Nicolson and Dean (1996) and Fawcett and Nicolson (1999) found that dyslexics exhibited substantial behavioural signs of a cerebellar dysfunction (e.g. poor performance on measures of postural stability, poor muscle tone, limb movement and coordination) compared to chronological and reading age controls. In addition, Fawcett and Nicolson (2001) reviewed neuroanatomical evidence suggesting that relative to controls, dyslexic adults showed less activation within the cerebellum and greater activation of the frontal lobes during the initial learning and subsequent reproduction of motor sequences (sequences of finger movements).

These authors suggested that the dyslexics were "by-passing the cerebellum to some extent, and relying on conscious strategies" (page 99).

These findings supported Nicolson and Fawcett's (1990) dyslexia automatization and conscious compensation hypotheses. The former relates to the cognitive consequences of a cerebellar deficit describing a difficulty with skill acquisition, specifically skill automatization. This refers to the process whereby skills (either motor or cognitive) through extensive practice, become fluent, smooth and less effortful. The latter accounts for how dyslexics are often able to compensate for their lack of automaticity through conscious effort (e.g. increased frontal lobe involvement).

Nicolson and Fawcett's three hypotheses can be organised into a causal chain whereby a cerebellar deficit can ultimately account for the majority of overt dyslexic symptoms. For example, a cerebellar impairment could result in the motor deficits often exhibited by dyslexics (e.g. clumsiness, poor balance and co-ordination and handwriting difficulties). A cerebellar deficit could also affect articulation (a fine motor skill) and speech processing and consequently phonological awareness. Poor phonological awareness results in reading and spelling deficits which are further compounded by a general automaticity deficit that affects automatic (e.g. fast and fluent) visual word recognition and spelling production.

These findings appear consistent with those of Stein et al (2001) who described the cerebellum as a "quintessentially magnocellular structure" (page 79) as it receives projections from the posterior parietal cortex and other magnocellular systems throughout the brain. Stein and Walsh (1997) suggest that "in dyslexics a particular magnocellular neuronal cell line that plays a major role in temporal processing in all sensory, sensorimotor and motor systems throughout the brain might be selectively damaged during early development" (page 151). Although there is evidence that the magnocells are regulated by the same genetic mechanism, individual differences in development abound. Stein et al (2001) suggested that it is these differences that determine the pattern of strengths and weaknesses in phonological, orthographic and motor skills that varies from one dyslexic to another.

1.6 Individual Differences

Fawcett and Nicolson (2001) maintained that 80% of dyslexics manifest signs of a cerebellar impairment whilst according to Stein et al (2001) two thirds (approximately 67%) exhibit "mild" (page 70) visual magnocellular deficits. It is unclear how visual, motor and phonological deficits interact i.e. whether they are caused by a single underlying brain abnormality, whether they result from different neurological impairments or whether there are correlated dysfunctions in different brain regions. These distinctions are highlighted by the Working Party of the Division of Educational and Child Psychology (1999) which maintained that it was "important to consider the extent to which available empirical evidence suggests that these [different theoretical accounts] should be regarded as alternative accounts of a unitary construct of dyslexia, as opposed to being regarded as accounts of different types of dyslexia" (page 44).

The ability of the phonological deficit hypothesis to explain numerous dyslexic symptoms has lead to the unitary or uni-dimensional view of dyslexia which stresses the causal role of a core phonological deficit (Stanovich, 1988). Within this model, individual differences in the behavioural manifestations of dyslexia are the result of varying degrees of phonological impairment. In contrast to the unitary view, is the perception that dyslexia can result from multiple causes (Watson and Willows, 1993). In this instance, reading difficulties are attributed to a variety of processing deficits (phonological, magnocellular or cerebellar) that either combine differentially at an individual level or manifest as discrete subtypes. Subtyping systems assume that dyslexia is not derived from a single etiological origin or that its manifestation is entirely individualized. Rather subtyping systems postulate the existence of homogeneous groupings within dyslexia. For example, Fawcett and Nicolson (2001) suggest the possibility of discrete magnocellular, cerebellar and mixed subtypes.

Unitary and multiple causation theories are similar in that both acknowledge verbal/linguistic deficits. However, whereas the unitary theory advocates the causal role of phonological processing in all dyslexic cases, multiple causation perceives this deficit as characteristic of particular subtypes of dyslexia only. The main

disparity between these positions is the relative importance placed on visual processing.

According to Watson and Willows (1993) and Rispens et al (1994) subtyping systems can be derived from clinical and statistical models. Clinical or inferential methods involve clinicians examining behaviour (e.g. reading and spelling performance) in order to subjectively group individuals who show similar patterns of performance. The majority of early subtyping studies employed this method and most identified auditory and visual subtypes as did subsequent empirical models that used statistical techniques such as cluster analysis or factor analysis. Rispens (1994) also described rationally defined and developmental classification systems. Rationally or theory defined subtyping systems group individuals that share certain characteristics whilst developmental approaches classify dyslexics according to the stage of literacy development at which they were potentially arrested.

Irrespective of the classification procedure or type of dyslexia (e.g. developmental or acquired), the subtyping literature is consistent in its identification of an auditory/verbal, linguistic, phonological or language based subtype, and a subtype characterised by some form of visual processing weakness. Watson and Willows (1993) concluded following a review of the subtyping literature that "a subgroup manifesting deficits in some aspect of visual perception, visual memory, or visuo-spatial-motor skills, has repeatedly emerged in both clinical and statistical classification research" (page 304). This visual subtype is however generally found to represent a smaller percentage of dyslexic children (Ellis, 1981, cited in Thomson, 1990) than those experiencing phonological difficulties.

Watson and Willows (1993) provide three possible interpretations of the relationship between visual processing deficits and poor reading. The first postulates the existence of a 'true' dyslexia subtype whose reading difficulties result from of some form of visual processing weakness (e.g. a magnocellular deficit). The second possibility relates to the findings of McKinney, Short and Feagans (1985) and Korhonen (1988) (described in Chapter 3) whose control subjects also clustered in perceptual and visuo-motor subtypes. Watson and Willows (1993) suggested that

14

variations in visual processing ability within groups of poor readers could reflect variation that occurs within the normal population and is not related causally to reading problems. Thomson (1990) also referred to this possibility, maintaining that "the differences between the children may not relate to the causes of reading retardation" (page 30). Finally, Watson and Willows (1993) suggest that visual processing deficits could only detriment reading when they co-occur with other processing problems (e.g. magnocellular deficits that co-occur with phonological processing problems).

Although dyslexia can be described at biological and cognitive levels (Frith, 1997), it is usually defined on the basis of a collection of observable behaviours or symptoms. A potential problem with this approach is the fact that these behaviours differ from one dyslexic to the next. In other words, considerable individual variation exists in terms of the type and/or severity of dyslexic difficulties. The purpose of the current research is to examine how factors such as sex differences and subtypes further our understanding of this diversity.

1.7 Aims of Research

Chapter 2 reviews the literature pertaining to cognitive sex differences, their biological underpinnings and their relevance to dyslexia. Although it is acknowledged that dyslexia may genuinely be more common in males than females, additional possibilities are also considered. For example, section 2.2 examines predictions derived from the referral bias hypothesis. This theory suggests that an equal number of males and females experience dyslexia, but that more males are referred for assessment (and consequently diagnosed as dyslexic) due to behavioural differences between the sexes.

Section 2.3 looks to the assessment process itself as a means of explaining the increased incidence of males within dyslexic samples. It is hypothesised that measures devised in response to the performance of predominantly male dyslexics may not be as sensitive to the identification of dyslexia in females. Defining dyslexia according to a male profile, and diagnosing it accordingly, is likely to result in more

15

males being identified than females. It is of particular interest to examine the performance of dyslexic females, the study of whom has been considerably neglected. Section 2.4 compares the performance of dyslexics, non-dyslexics males and females on the Bangor Dyslexia Test. Section 2.6 contrasts the performance of dyslexic and non-dyslexic females on five subtests from the Wechsler Intelligence Scale for Children (Wechsler, 1949), performance on which has been found to distinguish between dyslexic and non-dyslexic males. Section 2.7 also compares the performance of dyslexic males and females on the Wechsler Intelligence Scale for Children III^{Uk} (Wechsler, 1992) and examines the extent to which certain subtest profiles predict variance in reading, spelling and phonological processing. The final section of Chapter 2 (section 2.9) examines the response of dyslexic, non-dyslexic, males and females to different method of spelling instruction. The aim of this section is to determine how the cognitive strengths and weaknesses that define dyslexia interact with cognitive sex differences to influence learning style.

Chapter 3 examines dyslexia in adults. Previous research regarding the nature of dyslexia in adults is reviewed, and the performance of dyslexic and non-dyslexic adults is contrasted on a range of measures believed to identify dyslexia in adulthood. Using the regression procedure described by Castles and Coltheart (1993), section 3.2 investigates whether it is possible to divide a sample of adult dyslexics into meaningful subtypes. The final section of Chapter 3 (section 3.3) investigates potential predictors of symptom severity by examining the processes that predict the word recognition, reading comprehension and spelling ability of dyslexic and non-dyslexic adults.

1.8 Synopsis of Studies

STUDY I: *The Referral Bias Hypothesis.*

Study I investigated whether behavioural sex differences could be contributing to the increased incidence of male referrals to special educational services, by examining several predictions of referral bias theory.

In order to investigate whether males were perceived as more disruptive than females, class teachers within a non-selected school were asked to complete a behavioural screening questionnaire on a group of 94 (48 males and 46 females, age range 7.0 to 11.6) children with know no Specific Learning Difficulties. Single word reading accuracy was also assessed. Independent samples t tests revealed that males were rated as significantly more hyperactive and as having more conduct problems than females, however, they were also worse at reading. Either of these factors could, therefore, be contributing to the increased incidence of male referrals.

The behavioural ratings and reading ability of the 94 subjects from the non-selected school was then compared to 91 subjects from a specialist school, (52 males, 39 females, age range 7.3 to 11.3) 28 (18 males, 10 females) of whom were diagnosed as dyslexic. If referral is a response to behaviour, then individuals within the specialist school (28 of whom could have potentially been subject to a referral bias) should, on average, have been rated as more disruptive than individuals within the non-selected school. This did not appear to be the case, with no differences being identified between the two groups on any of the behavioural scales.

The possibility that behavioural problems co-occur with academic difficulties was also investigated by examining the relationship between reading and behaviour within the non-selected and specialist school samples. It was hypothesised that the relationship between reading ability and behaviour would be greater within the specialist school. This did not appear to be the case. Within the non-selected school reading ability was significantly correlated with all behavioural ratings. Within the specialist school only hyperactivity was significantly correlated with reading.

Differences between the dyslexics, non-dyslexics, males and females within the specialist school were also investigated. Dyslexics were more hyperactive and emotional than the non-dyslexics and these behaviours appeared to be related to their reading ability (although not always in the predicted direction). Although males were more hyperactive than females, hyperactivity was only related to the reading ability of females. No significant relationships were identified between any of the behavioural scales and the reading ability of males. These results do not support the hypothesis that males become more disruptive and females more withdrawn when experiencing learning difficulties.

STUDY II: *The Bangor Dyslexia Test*

Study II investigated possible sex differences on Bangor Dyslexia Test. Data was derived from Miles' (1993) sample of dyslexics and controls.

The mean number of pluses scored by 65 dyslexic and 65 non-dyslexic males on seven of the Bangor subtests, in isolation and combined (e.g. total number of pluses scored), was compared using an independent samples t-test. Dyslexic males scored significantly more pluses than non-dyslexic males on all measures. Similar findings were derived from a comparison of 41 dyslexic and 41 non-dyslexic females.

These groups (130 males, 82 females) where then used to investigate the interaction between group (dyslexic and non-dyslexic) and sex. A two-way analysis of variance was employed with the total number of pluses representing the dependent variable. No interaction between group and sex was apparent. However, dyslexics scored significantly more pluses than the non-dyslexics and males scored significantly more pluses than females. Subsequent t-tests revealed that the dyslexics scored more pluses on every measure, whilst the effect of sex was specific to three subtests: digits reversed, on which females scored more pluses than males, and months forwards and reversed, on which males scored more pluses than females.

Although the dyslexics and non-dyslexics were equivalent in terms of age and IQ grade, the males and females were not matched on these variables. When these

differences were controlled only a marginal main effect of sex was identified. Again, the total number of pluses scored by males was greater than that scored by the females. When the individual tests were examined, sex differences were restricted to the months forwards subtest, on which females continued to outperform males. When this subtest was removed and a revised total calculated accordingly, the effect of sex on the total number of pluses scored was non-significant.

STUDY III: *Comparison of Dyslexic and Non-dyslexic Females on the ACID and AVID Tests.*

Study III investigated the relative performance of 18 dyslexic and 18 non-dyslexic 9-10 year old females on the arithmetic, coding, information, digit span and vocabulary subtests of the WISC (Wechsler, 1949). Independent samples t-tests indicated that the non-dyslexics significantly outperformed the dyslexics on the information subtest only. Unlike data obtained from male samples, which indicated that non-dyslexic males outperform dyslexic males on three or more of the ACID or AVID tests, the performance of the dyslexic and non-dyslexic females only differed significantly on one of the five measures. These results present very little evidence for ACID/AVID profiles distinguishing between dyslexic and non-dyslexic females.

STUDY IVa: *Comparison of Dyslexic Males and Females on WISC-III* [UK]

Study IVa contrasted the performance of 70 male and 40 female dyslexics (age range 6.3 to 16.8) on WISC-III [UK].

Females outperformed males on digit span, coding and symbol search and consequently on the index of processing speed. The extent to which the ACID, AVID and SCAD profiles characterise the performance of male and female dyslexics was investigated by examining:

- Hierarchies of index scores and mean subtest scaled scores
- The incidence of full or partial profiles

19

- The frequency with which each subtest represented a significant strength or weakness

Results suggested that males perform relatively poorly on two ACID and two SCAD subtests (coding and digit span in both cases) and on one AVID subtest (digit span), whilst females only demonstrated a slight weakness on digit span. Overall, the findings suggest that full ACID, AVID or SCAD profiles do not characterise the performance of either dyslexic males or females and, therefore, do not represent a reliable means of identifying dyslexia.

STUDY IVb: *The Relationship Between WISC-III^{UK} Profiles and Various Measures of Literacy Attainment*

Study IVb investigated the relationship between the ACID, AVID and SCAD factors, and the individual subtests of which they are comprised, and the reading, spelling and phonological processing ability of the dyslexics analysed in section 2.7. ACID, AVID and SCAD factor scores were calculated for each dyslexic and the performance of males and females contrasted using independent samples t-tests. The dyslexic females significantly outperformed the dyslexic males on ACID and SCAD factors. Also, the females significantly outperformed the males on measures of reading, spelling and phonological processing. Pearson Product Moment correlations determined that the ACID, AVID and SCAD factor scores were highly correlated with the reading and spelling ability of both groups; however, the extent to which they correlated with phonological processing ability was considerably reduced in females relative to males.

Pearson Product Moment correlations and regression analyses were also performed in order to identify any relationships between reading, spelling and phonological processing and the individual subtests that comprise the three factor scores. The relationship between phonological awareness and reading and spelling was also investigated. Whereas phonological processing ability was predicted by vocabulary for both males and females, the predictors of reading and spelling differed across the

groups. For dyslexic males phonological processing predicted reading and spelling ability, whilst for females information was the single best predictor of literacy skills.

STUDY V: *Sex Differences and Remediation.*

Study V investigated the interaction between method of spelling instruction, sex and group (e.g. dyslexic or non-dyslexic). Fifty-three 11-year-olds (24 dyslexics and 29 non-dyslexics) were taught spelling lists by either a sound based phonics method or a visual-semantic method of spelling instruction.

Results indicated that the type of intervention and the sex of the subject had a non-significant effect on the spelling improvement of dyslexics and non-dyslexics. Additional analyses of dyslexic data, concerning the rate and endurance of spelling improvements also failed to identify an effect of sex. When other potential predictors of dyslexics' spelling ability were investigated, spelling improvement, following both methods of instruction, was correlated with non-verbal IQ and reading age (although this relationship was only significant for improvement following the visual-semantic intervention). A regression analysis indicated that reading ability was the best predictor of spelling improvement, following visual-semantic instruction.

STUDY VIa: *Comparison of Dyslexic and Non-dyslexic Adults*

Study VIa compared the performance of 45 dyslexic and 28 non-dyslexic adults (age range 16 to 37 years) on a range of measures typically used to assess dyslexia in children. Independent samples t tests did not identify differences between the groups on measures of non-verbal IQ, however, the non-dyslexics significantly outperformed the dyslexics on measures of vocabulary, auditory short term memory and processing speed. The performance of the non-dyslexics was also significantly in advance of the dyslexics on measures of literacy (including reading, spelling, reading comprehension and reading speed), phonology and orthography. With the exception of non-verbal IQ, all of the tasks used in the current study represent efficient means of distinguishing between typical dyslexic and non-dyslexic adults.

STUDY VIb: *Subtypes*

In accordance with the regression procedure described by Castles and Coltheart (1993), Study IVb used relative performance on measures of non-word and irregular word reading accuracy (standard criteria) and speed (efficiency criteria) to identify phonological and surface subtypes within a sample of adult developmental dyslexics. The standard criteria resulted in the classification of 65% of the dyslexics into subtypes (32.5% were phonological dyslexics and 32.5% were surface dyslexics). The efficiency criteria resulted in 77% of the sample being divided into subtypes (56% were phonological dyslexics and 21% were surface dyslexics). Subsequent analyses examined the utility of the phonological/surface classification system by comparing the subtypes on additional measures of phonological processing, lexical access and word knowledge. Irrespective of the classification procedure the phonological dyslexics were not significantly disadvantaged, relative to the surface dyslexics, on additional measures of phonological processing. The phonological dyslexics did, however, outperform the surface dyslexics on several measures of lexical access. When the standard criteria was used to define the groups, the phonological dyslexics outperformed the surface dyslexics on measures of word recognition and word knowledge. Phonological and surface dyslexics, classified by the efficiency criteria, did not differ on these measures. These findings cast doubt on the efficacy of Castles and Coltheart's procedure as a practical means of explaining individual differences amongst adult dyslexics.

STUDY VIc: *Severity*

Study VIc investigated predictors of symptom severity by examining the processes that predict the word recognition, spelling and reading comprehension ability of dyslexic and non-dyslexic adults. Regression analysis revealed that vocabulary and phonological processing/decoding ability predicted variance in the word recognition ability of both groups. Similarly, reading represented the primary predictor of spelling ability for both dyslexics and non-dyslexics. The groups differed, however, in that the spelling ability of the dyslexics also varied as a function of orthographic processing skill. The reading comprehension ability of the dyslexics was predicted

by word recognition and processing speed, whilst for the non-dyslexics, vocabulary and orthographic processing predicted variance on the reading comprehension task.

23

Table 1.1: Gantt chart showing when the data was collected for each study.

	10.1997	1998	1999	2000	2001	2002
Study I					▓	
Study II						▓
Study III & IV						▓
Study V		▓	▓	▓		▓
Study VI	▓	▓	▓	▓	▓	

2. SEX DIFFERENCES IN DYSLEXIA

2.1 Introduction

2.1.1 Cognitive Sex Differences

The cognitive abilities of males and females are, in general, remarkably alike, with no meaningful or practical differences existing between the sexes on measures of global intelligence (Vogel, 1990). However, differences have been identified on some of the abilities from which composite IQs are derived. Research examining cognitive sex differences has traditionally focused on verbal, visuospatial and mathematical processes (Maccoby & Jacklin, 1974). In general, males are perceived as exhibiting superior visuospatial and mathematical skills, whilst females are in advance of males on tasks that require the use of language. This tripartite taxonomy is now viewed as an over simplification (Halpern, 1997, 2000) as there are verbal tasks on which males outperform females and visuospatial and quantitative tasks on which females outperform males. The following review provides a brief account of cognitive sex differences, the measures on which they are identified, their possible biological origins and their potential impact on the aetiology and expression of dyslexia.

The most consistently identified cognitive sex differences occur on measures of visuospatial aptitude. This is an umbrella term that encompasses numerous skills that do not depend on verbal ability. The extent to which the sexes vary depends on the type of ability assessed. One of the largest and most reliable sex differences is the male advantage on mental rotation tasks. For example, Masters and Sanders (1993) reviewed 14 studies (published between the years 1975 and 1992) concerning sex differences in teenagers and young adults, on Shepard and Metzler's (1971) Mental Rotations Test. Not only did males consistently and significantly outperform females but the magnitude of the difference, in terms of effect size, remained stable over time. Halpern and Wright (1996) and Voyer et al (1995) also identified a male superiority on measures of mental rotation.

Mental rotation tasks assess spatial orientation by requiring subjects to imagine what a given object would look like from a different perspective, when rotated in two or three dimensional space. Performance on mental rotation tasks is correlated with the ability to learn novel routes and navigate mazes, tasks at which males excel (Galea and Kimura, 1993; Moffat, Hampson and Hatzipantelis, 1998; Astur et al 1998). Kimura (1999) maintained that the ability to construct 'cognitive maps' and learn or navigate routes required the recognition of objects from different orientations; an ability assessed by mental rotation tasks. Studies have also shown that males and females use different navigational cues, males rely on distances and directions whilst women predominantly use landmarks. Similar findings have been identified in animal experiments. For example, Williams, Barnett and Meck, (1990) found that male rats use geometric cues to navigate a maze whilst female rats rely more on landmark cues.

Males also outperform females on measures of spatial perception such as the Embedded Figures Test (Miller 2001; Springer 1997), the Rod and Frame Test (Bradshaw 1989), and the Water Level Test (Robert and Ohlmann 1994, Vasta et al 1996). The embedded figures test requires subjects to distinguish a simple image or geometric form hidden within a more elaborate image or form. In order to complete the rod and frame test participants have to identify the true horizontal, or the true vertical, within a distracting context (e.g. a tilted frame). Similarly, the water level test requires subjects to draw a line indicating the water level in containers set at various angles. The ability to accurately perform the water level task is dependent on an understanding of the concept (e.g. water levels remain horizontal) and, as in the rod and frame test, the ability to maintain awareness of the true horizontal within a distracting environment. Although fewer women demonstrated knowledge of the concept (Halpern 2000), Kimura (1999) maintained that the female disadvantage ensued problems with the spatial perception aspect of the task. Even when the concept was explained, females continued to demonstrate poorer performance than males. Kimura (1999) suggested that the relatively weak performance of females on the water level, rod and frame and embedded figures tests was a reflection of their greater 'field-dependence' (Witkin, 1967). Females find it harder than males to extract target information from within a distracting context.

In addition to spatial orientation and spatial perception, males outperform females on measures of spatial visualisation (e.g. the Paper folding test) and tasks that require spatial-temporal judgements, such as estimating distances, velocity or time (Schiff and Oldak, 1990; Smith and McPhee, 1987).

Mathematics is another area at which males are perceived as superior to females. Research suggests that more male children are identified as mathematically precocious and males grossly outnumber females in groups of mathematically gifted adults (Halpern 2000); a finding which appears as resistant to social change as sex differences in chess (Bradshaw 1989). Advanced mathematics (e.g. geometry, trigonometry and calculus) requires good visuospatial skills, a factor that could potentially contribute to the disproportionate number of males studying higher maths. As with visuospatial ability, sex differences in mathematics depend on the specific nature of the maths task. For example, males outperform females on measures of mathematical reasoning and mathematical problem solving, whilst females do better on tests of mathematical calculations (Kimura, 1999; Springer, 1997).

Finally, males are better at aiming and intercepting projectiles (Watson and Kimura, 1991; Hall and Kimura 1995) and they demonstrate superior proportional (Meehan 1984), mechanical (Stanley et al 1992, cited in Halpern, 1997), and scientific reasoning skills (Hedges and Nowell 1995).

Sex differences on visuospatial tasks are evident from an early age. Kimura (1999) refers to the findings of Rosser et al (1984), Johnson and Meade (1987), Kerns and Berenbaum (1991) and Vederhus and Krekling (1996), all of whom identified superior performance of prepubertal boys on various measures of visuospatial ability. Although some authors (Feingold, 1988) have suggested that cognitive sex differences are being reduced as a result of different socialisation or child rearing practices, others maintain that this is not the case (e.g. Masters and Sanders, 1993). Sex differences favouring males on various measures of visuospatial ability are evident cross-culturally and are even paralleled within the animal kingdom (Kimura 1999).

Females have been found to outperform males on one spatial task – memory of an objects location. Females are better at remembering the position of objects (familiar or unfamiliar) in a spatial array and consequently at identifying those objects which have been displaced (Eals and Silverman, 1994). Women also outperform males on the pelmanisms task (McBurney, Gaulin, Devineni and Adams, 1997). In an adaptation of Eals and Silverman's (1992) memory location task, James and Kimura (1997) demonstrated (in accordance with Eals and Silverman) that females were superior to males at detecting when two objects in an array exchanged locations. However, male performance improved (resulting in no differences between the sexes) when objects were moved to previously unoccupied locations. It appeared that for females it was the object that was important whilst for males it was the location. James and Kimura (1997) suggested that the storing of location memory might be organized differently in males and females. Specifically they hypothesized that "women may be more likely to process object identity and object location together, that is, by overlapping brain systems; whereas men may tend to process the identity of an object and its location separately" (Kimura, 1999, page 51).

Females also outperform males on memory tasks that require the recall of verbal material or material that can be encoded verbally (e.g. a visual memory task that uses pictures that can be easily labelled or named). For example, a female advantage has been identified on digit span tasks (Kail and Seigel, 1978; Jensen and Reynolds, 1983), word span tasks (Kramer et al, 1988; Geffen et al, 1990) and tasks that require remembering the content or meaning of continuous text (Owen and Lynn, 1993; Mann et al, 1990). Females also outperform males on measures of associative memory (Birenbaum et al, 1994; Hedges and Nowell, 1995) e.g. remembering the connections between items such as object and object name. In addition to sex differences in the recall of visual verses verbal material, researchers have also investigated sex differences in incidental verses intentional memory and episodic verses semantic memory. Irrespective of these distinctions, if the task can be verbally mediated, females outperform males. The female superiority on verbal memory tasks is one of the largest sex differences favouring women, it is evident throughout the life span and appears unaffected by cultural differences.

It is not just on measures of verbal memory that females outperform males; females are perceived as possessing superior verbal skills in general. Verbal ability refers to many different aspects of language usage and the extent of the sex difference depends on the type of verbal task. Sex differences in verbal abilities occur from a very early age, with girls learning to speak earlier than boys. During infancy (i.e. first five years of life) girls produce longer, more diverse and complex utterances than boys (Horgan, 1975) and they demonstrate a faster rate of vocabulary growth (Huttenlocher et al, 1991). This verbal advantage continues throughout school with females outperforming males on measures of spelling, grammar and punctuation (Martin and Hoover, 1987; Hyde and Linn, 1988), reading (Vogel 1990), reading comprehension (Martin and Hoover, 1987; Hedges and Nowell 1995) and creative writing (Halpern 2000).

One of the most significant sex differences favouring females has been identified on verbal fluency tasks (Hines, 1990). Kimura (1999) described how females outperformed males on measures of alliteration and rhyme fluency but not necessarily on measures of semantic fluency. These findings caused her to hypothesise that females had "better brain representation" (page 92) of phonemes, which would be consistent with their superior articulation in infancy and their better spelling skills in adulthood.

Sex differences favouring females on measures of verbal memory and verbal fluency are both pronounced and enduring, representing, along with spelling and grammar, the only verbal tests on which females continue to outperform males in adulthood.

A female advantage has also been identified on measures of perceptual speed and perceptual motor abilities (Born et al, 1987; Kimura and Hampson, 1994). These tasks involve the rapid scanning of collections of stimuli (e.g. pictures, shapes, symbols, numbers or letters) in an attempt to locate target items (e.g. WISC symbol search) or require subjects to establish associations between stimuli at speed (e.g. WISC coding). Both types of task required fine motor skills or manual dexterity which represents another skill at which females excel (O'Boyle and Hoff, 1987; Hall and Kimura, 1995; Gouchie and Kimura, 1991).

Instead of using the visual, verbal, mathematical taxonomy to describe ability differences between the sexes, Halpern (1997, 2000) examined the underlying cognitive processes that support the various tasks on which the sexes have been found to differ. She concluded that females are superior to males on tasks that require rapid memory access, whilst males are better at sustaining and manipulating information in visuospatial memory.

"Females, on average, score higher on tasks that require rapid access to and use of phonological and semantic information in long term memory, production and comprehension of complex prose, fine motor skill, and perceptual speed. Males, on average, score higher on tasks that require transformation in visual-spatial working memory, motor skills involved in aiming, spatiotemporal responding and fluid reasoning, especially in abstract mathematical and scientific domains" (Halpern 1997, page 1091).

Various hypotheses have been proposed as a means for accounting for cognitive sex differences. For example, Kimura (1999) maintained that the division of labour in our evolutionary past could have shaped the cognitive make up of contemporary man. Alternatively, biological or neurological differences in brain organisation could contribute to the differential cognitive development of males and females.

2.1.2 Sex Differences in Brain Organisation

With the exception of size (male brains are 10 to 15% larger than female brains), no overall anatomical differences exist between male and female brains. However, evidence suggests that certain structures may function differently in males and females. For example, the Hypothalamus, the Hippocampus and the Corpus Callosum are considered sexually dimorphic brain regions (see: Kimura, 1999; Halpern, 2000).

The Corpus Callosum is a band of axons that connect the two hemispheres and sex differences have been identified within specific regions of this structure. For example, the Splenium has been found to be larger and more bulbous in females. The Anterior Commissure and the Massa Intermedia are also larger in females than

males. The finding that more nerve fibres connect the left and right hemisphere in females has been used to infer better interhemispheric connectivity in females. In other words, there is better communication, or transfer of information, between the two halves of the female brain than there is between the two halves of the male brain. Sex differences in interhemispheric connectivity is related to the idea that cognitive functions are organised differently within male and female brains.

The hemispheres vary in the extent to which they are able to learn and control various skills. Perceptual studies have shown that, for the majority of people, the right hemisphere specialises in the processing of spatial information, attention, emotion and music, whilst the left hemisphere mediates linguistic functions and the processing of rapidly changing auditory/acoustic information (Galaburda, 1985; Lambe, 1999). According to Halpern (2000), this is not an "either/or division" (page 201) but instead reflects one hemisphere's relative dominance and adeptness over the others. These functional differences are present from birth and interact with factors like handedness. For example, approximately 95% of right-handers have language lateralised within their left hemisphere and visuospatial functions in the right. Only 70% of left-handers show this pattern. It is unclear how handedness and sex interact. For example, there is a greater incidence of left handedness in males, however, left handedness is associated with bilateral representation of language functions, a pattern supposedly more common in females.

Research suggests that male and female brains are organised differently. During the early 1970's Levy proposed the 'Cognitive Crowding Hypothesis' in which cognitive abilities, represented within the same hemisphere, competed for 'neural space'. According to Levy (1976), females were "less lateralized then males because of sex-related biological differences in the rate and pattern of development" (Halpern, 2000, page 211). Levy maintained that language was represented bilaterally (established in both hemispheres) within the female brain, whereas males had an asymmetrical cortical arrangement (language functions in the left hemisphere, visuospatial functions in the right). Levy's theory accounted for the relative female weakness on measure of visuospatial functioning by proposing a 'cortical trade off', whereby

verbal functions encroached on the processing resources of the right hemisphere to the detriment of spatial skills.

The idea that cognitive functions are more lateralised within male brains is supported by numerous perceptual studies (Bryden, 1988; Hines, 1990; Hellige, 1993; Voyer, 1996). For example, verbal dichotic-listening tasks have identified right ear (left hemisphere) advantages for males more often than for females. Similarly, tachistoscopic studies have identified left visual field (right hemisphere) preferences for non-verbal material and right visual field (left hemisphere) advantages for verbal material that are more pronounced in males than females. Finally, dichaptic stimulation tests of tactile perception have revealed a specific left hand (right hemisphere) advantage for male children only (Iaccino, 1993; Springer, 1997).

Studies of stroke/tumour cases, lesion data and post-mortems also support the hypothesis that male and female brains are organised differently. For males, damage to the left hemisphere has been found to impair verbal skills to a greater extent than non-verbal skills (there is a greater incidence of aphasia in males following lesions to the left hemisphere), whilst damage to the right hemisphere resulted in the converse pattern. Not only was this interaction less apparent in female patients, but females were more prone to verbal deficits following lesions to the right hemisphere (for a review see Lambe, 1999). Similarly, Frith et al (2001) found that males experienced reading and spelling impairments, following left hemisphere lesions only, whilst females showed no significant impairments following damage to either hemisphere. These findings support the idea that visuospatial and language functions are more bilaterally represented in females.

More recent studies, using EEG recordings, have identified greater right hemisphere activation (specifically the right frontal lobe) in males during a spatial task compared to females, who showed bilateral activation of left and right frontal and temporal regions (Gill and O'Boyle, 1997). Shaywitz (1996) determined (using fMRI) that in males the left inferior frontal gyrus was activated during phonological processing tasks, whereas both the left and the right inferior frontal gyrus were engaged in females.

Hugdahl (1993) maintained that "hemispheric asymmetry is an important modulation of cognitive function" (page 135). Greater lateralisation (as seen in males) was perceived as beneficial for visuospatial abilities, whereas bilateral representation was described as facilitating language, thus accounting for the female advantage (Bryden, 1981; Tallal and Fitch, 1993).

Although the above perception of sex differences in brain organisation prevails, the consistency with which these differences are identified and their reported magnitude varies considerably. Iaccino (1993) maintained that to refer to males as more functionally lateralised and females more bilateral was potentially an over generalisation, and that information processing strategies and attentional factors interacted with cortical organisation resulting in considerable individual differences. Halpern (2000), whilst acknowledging the inconsistencies within the literature, noted that when differences in hemispheric specialisation were identified "they were almost always in the same direction – females less lateralized than males. If these were spurious findings, then we could expect the results to go in either direction about equally often" (page 212).

Sex differences are also apparent with regard to specialisation within the hemispheres. For example, the regions of the brain engaged in language functions and manual dexterity (skills at which females tend to outperform males) are focally represented in the left anterior region for females and more diffusely organised within the left posterior region for males (Lambe, 1999; Halpern, 2000).

Differences exist both between and within the cerebral hemispheres of males and females. Factors that are believed to contribute to these differences include maturation rate and/or hormonal exposure during prenatal and early postnatal development.

2.1.3 Sex Differences in Maturation Rate

Waber (1981) maintained that sex differences in cognition and hemispheric specialization reflected the different maturation rates typical of each sex. Males and

females develop at different rates. By the second trimester the female foetus is in is advance of the male with regard to physical and neurological development. This continues until puberty, which females typically reach two to three years before males (Nass, 1993). Waber proposed that the hormonal fluctuations responsible for the timing of puberty (which increase in circulation from about age 7) also accounted for sex differences in cortical organization and consequently cognition. Later pubital development (typical of males) allows for language functions to develop exclusively in the earlier maturing left hemisphere. Late maturers consequently demonstrate greater asymmetries or hemispheric specialization. Early maturers (typically females) "would be more likely to show functional plasticity between the hemispheres and so could represent the linguistic functions more bilaterally than late maturers" (Iaccino, 1993, page 141). Maturational differences and consequent variations in cortical organisation influence verbal and visuospatial abilities. Late maturers show the male pattern of cognitive abilities (e.g. spatial abilities superior to verbal ability), whilst earlier maturers show the female pattern of relative strengths and weaknesses (verbal skills in advance of visuospatial skills).

Given that females are developmentally in advance of males, they should achieve various 'cognitive milestones' (e.g. onset of speech) at a younger age. According to Shaywitz et al (1991) the maturational advantage of females makes the development of males appear delayed. Males are consequently more likely to be misdiagnosed as having a learning disability. Alternatively, the slower maturation rate of males could prolong the 'critical period' during which brain injury could occur, thus predisposing males to a variety of neurodevelopmental and psychiatric disorders. For example, delayed speech, stuttering, autism, dyslexia, epilepsy, attentional deficit disorders, mental retardation, learning disabilities and emotional problems occur more frequently in males than females (Bradshaw, 1989; Halpern, 1997).

There are several potential problems with Waber's maturation hypothesis. For example, functional asymmetry (at least for language) and cognitive sex differences are evident from infancy and consequently occur well before puberty. There is also some contention regarding the hypothesis that the left hemisphere develops earlier than the right. Recent research (Halpern, 2000) suggests the opposite, that the left

hemisphere usually develops more slowly than the right. Waber's hypothesis that hormones influence cognition is however, well supported. Although not maturation rate, or the timing of puberty per se, the hormonal differences, of which these are a reflection, do appear to play a role in cognitive development.

2.1.4 Hormonal Differences

At conception, male and female embryos are identical. The genetic make-up of the sex chromosomes (e.g. female XX or male XY) directs the differentiation of the gonads into either ovaries or testes which secrete sex hormones. Males and females produce the same hormones that vary in terms of concentration. For example, the testes produce greater quantities of androgens in males (androgen concentrations are on average 17 times higher in males than females), whilst in females the ovaries secrete higher concentrations of oestrogen and progesterone. The adrenal glands produce both male and female hormones. It is essentially the presence, or absence, of testosterone that is responsible for sexual differentiation. If testosterone is not produced, or the body's cells do not have operational androgen receptors, the foetus will develop as female even if genetically male (e.g. androgen insensitivity syndrome).

In addition to the development of the genitalia, hormones also influence the sexual differentiation of the developing brain, by directing the formation of neural pathways. The effects of hormones, on the development of cognition, are divided into two categories, organisational and activational. Organisational effects refer to the hormonal environment during critical stages of prenatal and postnatal development, that determine the organisation or structure of the developing brain. For example, testosterone levels are much higher in males than females in the prenatal period ranging from approximately 8 to 24 weeks and from birth to the first five months of postnatal life. Testosterone directs masculinization by altering gene expression. Within the vertebrate brain, specific groups of motor neurons act as steroid target tissues accumulating testosterone. These receptors are involved in specific, often sexually dimorphic, operations. Male testosterone levels peak again at puberty; however, in this instance the effects are considered activational, resulting in

35

short lived (determined by duration of hormonal exposure) activation of "neural events" (Halpern, 2000, page 156).

The hormonal environment during critical stages of development and hormone levels throughout life can affect cognition, contributing to the male/female pattern of relative strengths and weaknesses previously described. Data pertaining to the effect of hormones on cognitive ability is derived from several sources. For example, animal studies, the study of individuals exposed to synthetic sex hormones (e.g. transsexuals awaiting sex reassignment surgery), or individuals with abnormal hormone levels due to some form of endocrine condition (e.g. congenital adrenal hyperplasia). Finally, the effect of naturally occurring hormone fluctuations (e.g. normal seasonal, monthly or diurnal fluctuations) on cognition has also been investigated.

Evidence from these sources suggests that females with high levels of male hormones manifest improved spatial skills. For example, Resnick et al (1986) studied a sample of post-adolescent individuals with congenital adrenal hyperplasia (CAH), a condition resulting in prenatal exposure to high levels of adrenal androgens. Females exposed to high androgen levels were found to be superior to their non-exposed female siblings on measures of spatial functioning. Similarly, Grimshaw et al (1995) found that females with higher concentrations of prenatal testosterone (levels of testosterone within the amniotic fluid assessed during the second trimester of pregnancy) performed faster than females with lower levels of prenatal testosterone on a mental rotation task at age 7. Schute (1983) and Gouchie and Kimura (1991) found that 'normal' adult females with relatively high concentrations of androgens within their blood, or high levels of salivary testosterone, outperformed females with relatively low androgen levels on spatial tasks. Finally, Van-Goozen et al (1995) found that androgen supplements increased spatial ability in female-to-male transsexuals (individuals who receive large quantities of exogenous hormones prior to sex reassignment surgery).

The detrimental effect of male hormones on the verbal ability of females has also been documented, i.e. females with high levels of male hormones show reduced

verbal skills (Van-Goozen et al, 1995). Helleday et al (1994) found that females with CAH demonstrated a verbal disadvantage, relative to a group of non-affected age matched controls. The authors concluded that increased prenatal exposure to androgens resulted in a "more masculine cognitive pattern" (cited in Halpern, 2000, page 161).

The opposite pattern (e.g. improved verbal skills and reduced spatial ability) has been observed in males exposed to high levels of female hormones. For example, Reinisch and Sanders (1992) compared a group of boys exposed prenatally to a form of synthetic oestrogen (diethylstilbestrol DES mistakenly believed to prevent miscarriages) to their unexposed male siblings (used to infer some control over genetic and environmental variables). Oestrogen exposure was associated with reduced spatial skills and hemispheric laterality, a pattern normally observed in females. Conversely, estrogen treatment given to male-to-female transsexuals was found to improve verbal memory (Miles, Green, Sanders and Hines, 1998).

Similar results are observed within the sexes (i.e. females exposed to high levels of female hormones show increased verbal ability and reduced spatial skills). For example, the effect of the hormone fluctuations that occur in females during the menstrual cycle has been studied (Hampson and Kimura, 1988; Hampson, 1990; Saucier and Kimura, 1998; Hausmann et al, 2000). When levels of oestrogen and progesterone were at their highest (midluteal phase), performance on measures of verbal expression and manual dexterity improved relative to phases in the cycle when hormone levels were low (menstrual phase). The reverse pattern was identified with regard to spatial skills, the higher the concentration of female hormones the lower the performance on spatial tasks.

As described previously, certain cognitive sex differences persist into adulthood and even old age. For example, 80 year old females have been found to outperform males of a similar age on measures of verbal memory, whilst males still demonstrate a spatial advantage. Drake et al (2000) identified an association between high levels of estrodiol and improved verbal memory and low levels of estrodiol and enhanced visual memory in elderly women. In recent years the incidence of postmenopausal

women taking estrogen replacement therapy has increased, as it reduces the risk of heart disease and osteoporosis. Estrogen therapy has been found to improve short term memory (Halpern 2000) and fine motor skills (Bradshaw 1989). In addition, it reduces the incidence (by as much as 50%) and symptom severity of Alzheimer's disease in women. According to Halpern (2000) "estrogen replacement has observable effects on the brain. It spurs neuronal growth and increases the speed of communication among the brain's neurons". Wolf and Kirschbaum (2002) also reported that estradiol exerted a protecting influence on the verbal memory skills of older women.

The relationship between female hormones and cognitive abilities appears reasonably straight forward. Whether male or female, exposure to high levels of female hormones appears to improve verbal skills and reduce spatial ability. Male hormones however, have a differential effect on the sexes. Whereas increased concentrations of male hormones reduce verbal ability in both males (Wolf and Kirschbaum, 2002) and females, high androgen levels are only correlated with increased spatial skills in females.

Kimura (1999) reviewed research concerning naturally occurring seasonal and daily fluctuations in testosterone levels. For example, male testosterone levels are higher in the autumn than in the spring and highest in the morning decreasing throughout the day. Males' spatial ability was relatively better in the spring when testosterone levels were reduced (Kimura and Hampson, 1994) and better latter in the day (as opposed to in the morning). These findings are consistent with those of other researchers (Berenbaum et al, 1995; Gouchie and Kimura, 1991; Moffat and Hampson, 1996; Schute, 1992) who have identified a negative relationship between spatial ability and androgen levels. These findings suggest that the optimum androgen level for spatial ability is within the intermediate/low male range (which is still relatively high for females).

With the exception of the correlation between spatial skills and androgen levels in males, this research has identified a consistent relationship between hormones and cognition. Female hormones are associated with the female pattern of relative verbal

strength and spatial weaknesses, whilst male hormones (in general) are associated with the opposite cognitive profile.

2.1.5 Environmental Factors

It is worth noting that in addition to biological mechanisms, environmental factors also contribute to sex differences in cognition. People do not exist within a social vacuum. Social reinforcement from parents and peer groups, observational learning and sex-role stereotypes result in males and females adopting different interests, values and attitudes. These socialization pressures interact with biological predispositions, to the extent that the individual effects of each are inseparable. One possibility is that sex differences are amplified by socialization practices. For example, females are less likely to engage in spatial activities to the same extent as males. This could result from a biological weakness perpetuated by the fact that females are encouraged to pursue alternative interests; failure to engage in spatial activities prevents improvement (Michel, 1981). It is difficult to separate the effects of practice and experience from biological tendencies, i.e. whether a biologically determined advantage results in greater participation in certain activities, or whether experience and practise result in greater ability. It is also difficult to determine whether training improves performance by affecting the underlying ability or by promoting the use of more efficient strategies learned through experience. Petersen (1981) reasoned that "we are biological bodies, with psychological characteristics, functioning within complex social systems". We are continually influenced by biological, psychological (e.g. gender identity) and social factors that interact reciprocally.

2.1.6 Sex Differences and Dyslexia

A considerable amount of research documents the excess of males identified with dyslexia. Following a review of the literature, Goldberg and Schiffman (1972) maintained that the ratio of males to females within clinic populations varied from 3.3:1 to 10:1. Critchley (1970) quotes ratios that range from 2:1 to 5:1, whilst

Finucci and Childs (1981) identified ratios of males to females that varied from 3:1 to 15:1. The ratio most frequently cited is 4:1 males to females (Critchley, 1970).

Theories of dyslexia have incorporated the aforementioned hormonal effects on brain organisation and cognition to account for the increased preponderance of males within dyslexic populations. The male hormone testosterone has been specifically implicated in a number of theories pertaining to the aetiology of dyslexia.

Testosterone is believed to have an effect on the development of the Planum Temporale (PT). This is a language related cortical area, concerned with the perception of speech sounds and is located on the superior surface of the temporal lobe (supratemporal region of the auditory association cortex). The PT is typically asymmetrical in favour of the left hemisphere (85% of population); however, post mortem studies have uncovered unusual symmetry in dyslexic subjects (Galaburda 1985). Androgen secretion during development has been found to inhibit ontogenetic cell death (the normal culling of neurons that occurs during the development of the nervous system) within the right hemisphere. This increases the volume of the right planum and overall symmetry which is believed to contribute to language disorders (Kelly, 1993). Larsen et al (1990) identified abnormal planum symmetry in their group of dyslexics (5 out of 19) with pure phonological deficits. These authors concluded that there was a relationship between planum symmetry and dyslexia and more specifically, between planum symmetry and phonological decoding.

Another theory linking testosterone to the disproportionate number of male dyslexics was proposed by James (1992), Tallal and Fitch (1993) and Nass (1993). James (1992) suggested that high levels of parental testosterone at conception predisposed to male offspring, and that there was a "biological propensity of parents of dyslexic children to produce a high proportion of boys" (page 532). Tallal and Fitch (1993) endorsed this theory but referred specifically to the role of the mother. They found that females with language/learning disabilities had a disproportionate number of sons. This finding was linked to abnormal levels of maternal testosterone that predisposed to male births and a susceptibility to learning difficulties later in life (Nass, 1993).

Geschwind and Galaburda (1985 a-c) proposed a "set of loosely related hypotheses" (Hughahl, 1993, page 138) marking testosterone as the causal factor behind left handedness, immune disorders, cerebral lateralisation and dyslexia. The theory maintained that testosterone suppressed or slowed neuronal development of the left hemisphere, specifically the left posterior region associated with the PT. This occurred in utero and continued during the first two years of postnatal life. Exposure to testosterone disturbed standard cortical architecture of the left hemisphere, causing anatomical and functional abnormalities which resulted in impaired verbal skills and dyslexia. In response to the delayed development of the left hemisphere compensatory growth occurred in the right, causing anomalous dominance (left handedness and greater involvement of the right hemisphere in language functions). Increased right hemisphere development resulted in enhanced abilities in those skills mediated by the right hemisphere (e.g. visuospatial skills). The Testosterone Hypothesis was therefore able to account for the visuospatial 'giftedness' sometimes observed in dyslexics (Galaburda, 1990; McManus and Bryden, 1991).

The testosterone hypothesis offered an explanation of left hemisphere deficits and corresponding right hemisphere strengths. It also accounted for the prevalence of males within dyslexic populations by means of their increased susceptibility to high levels of testosterone. Testosterone was also implicated as a causal factor of dyslexia in females. In this instance, dyslexia ensued exposure to testosterone from the maternal ovaries and adrenals.

Galaburda (1985) reported that the cortical and subcortical alterations found in dyslexic brains were primarily in the left hemisphere. Similarly, Tallal and Fitch (1993) described the neuropsychological profile associated with dyslexia as indicative of a "specific left-hemisphere dysfunction" (page 171). However, this appears more representative of male dyslexics than female dyslexics. Lambe (1999) reviewed the findings of various studies that had conducted post-mortem examination of dyslexic brains (e.g. Humphreys et al, 1990; Galaburda et al, 1979, 1985, 1994; Kaufmann et al, 1989), concluding that the pattern of microscopic cortical abnormalities identified within dyslexic brains differed as a function of sex. For example, ectopias (displaced nests of neurons caused by disrupted neural

migration) were more common in males than females. Furthermore, whereas ectopias were predominantly within the left hemisphere of males they were present bilaterally within the brains of female dyslexics. Females conversely, showed a greater incidence of cortical scars. Ectopias and cortical scars are caused by similar injuries to the brain. If the insult occurs during a period of neural migration ectopias result, whereas later injuries produce cortical scars. These findings are potentially a reflection of the differential maturation rate of males and females (females maturing faster than males).

The bilateral representation of language functions within the female brain could also result in females being less susceptible to dyslexia, in that they are better able to compensate for unilateral brain injuries (Tallal and Fitch, 1993; Shaywitz, 1996). Lambe (1999) maintained that "gender and level of sex hormones may affect the acute or long-term consequences of brain injury" (page 526). Not only are females better able to overcome unilateral dysfunctions but males show an increased susceptibility to the obstetrical complications that potentially result in such dysfunctions (McKeever, 1981; Nass, 1993).

It is unclear how the bilateral representation of language functions (typical of females), with its potential advantages for verbal skills and protection against dyslexia, relates to the long standing idea that dyslexia is associated with incomplete/reduced dominance (Orton, 1937; Geschwind and Galaburda, 1985). Bryden (1981) described the functional asymmetry of males as 'complementary specialization' and the symmetry typical of females as 'non-complementary'. He concluded that "it is difficult to argue that abnormal cerebral lateralization is in any way causing dyslexia. Rather, the problem arises in those individuals [males] with the most common pattern of lateralization" (page 91). Hugdahl (1993) describes other types of abnormal brain asymmetry that have been associated with dyslexia. In addition to increased bilateralization, a maturational lag in lateralization, deficits in interhemispheric integration and a left hemisphere deficit have all been implicated in dyslexia.

Iaccino (1993) described research suggesting that different subtypes of dyslexia (e.g. auditory-linguistic and visuospatial) resulted from either left or right hemisphere disturbances. Bakker's (1979) perceptual (P-type) and linguistic (L-type) subtypes are an example of this. Bakker and Moerland (1981) posited that various stages of the learning to read process were mediated by the different hemispheres. Right hemisphere, holistic, perceptual reading strategies were followed by left hemisphere, analytic, linguistic-semantic strategies. The authors believed that females advanced to more sophisticated linguistic strategies prior to males. Reading problems in males were attributed to the persistent use of right hemisphere, visuospatial strategies (perceptual dyslexia) whilst poor reading in females resulted from the untimely use of left hemisphere linguistic approaches (linguistic dyslexia).

Numerous researchers have described females as better able to 'tolerate' deficits in literacy skills (Finucci and Childs, 1981). Following a review of the literature, Vogel (1990) concluded that before females were referred for assessment they had to fail for longer, as evidenced by the fact that females tended to be diagnosed at an older age than males. They had to manifest significantly lower IQs, more severe literacy difficulties and show larger ability / attainment discrepancies than males. Whereas teachers viewed girls as more tolerant, adaptive and better able to compensate for their difficulties (Nass, 1993), males were seen as referral priorities. Different aspects of environmental manipulation have been found to have a greater impact on the reading ability of males than females. For example, interest in the material being read and/or the motivation to read, teaching standards, anxiety, reinforcement and socioeconomic status have been found to affect the reading performance of males to a greater extent than females (McGuinness, 1981; Defries et al, 1993). According to Pennington (1988, cited in Vogel, 1990) the acquisition of component reading skills is "protected" in females by genetic and environmental factors.

The differential referral rates of males and females could stem from biological, cognitive, behavioural or social factors. Biological or neurological differences could mean that dyslexia is genuinely more common in males than females. Indeed, males show an increased susceptibility to obstetrical complications that could potentially

result in nervous system damage, and males are far more prone to a variety of neurodevelopmental and psychiatric disorders than females.

The detrimental effects of male hormones and the protecting influence of female hormones, on those aspects of cognition typically associated with dyslexia, could result in males being more often, or more severely, affected than females. The effects of hormones on cognition may be mediated by their influence on brain organization. The bilateral representation of language functions allowing females to compensate for dyslexia more often than males. Lambe (1999) concluded, following a review of neuropsychological evidence, that "gender differences are relevant to the symptoms and neuroabnormalties characteristic of dyslexia" (page 532) and that "it would be surprising if developmental dyslexia had both identical symptoms and identical causes in males and females" (page 529).

Alternative theories assert that dyslexia is as common in females as in males, but for some reason females are not diagnosed as frequently. One possibility is that dyslexic deficits are more easily overcome by females or present as less severe in females. The 'normal' cognitive differences that distinguish the sexes could reduce the expression of dyslexia in women. Females show comparatively superior performance on those aspects of language processing, (including phonological processing; Raymond, 1999) and memory, on which dyslexics consistently show deficits. McGuinness (1981) maintained that "the strongest predictor of reading ability is phonological encoding and a general language facility. Females appear adept in both" (page 68). This natural language facility could reduce the impact of dyslexia in females.

An alternative possibility is that female dyslexics manifest a "different psychometric profile" (Vogel 1990, page 47) to that of males. In this instance, the under identification of dyslexic females is a consequence of what Vogel (1990) referred to as a 'mismatch' between the difficulties experienced by the female dyslexic and the referral agent's / assessor's idea of dyslexia. For example, research on primarily male dyslexics has consistently shown depressed scores on four subtests (arithmetic, coding, information and digit span) of the Wechsler Intelligence Scale for Children

(Wechsler, 1949, 1974). This male profile of difficulties (referred to as the ACID profile) has subsequently come to represent dyslexics in general. Similarly, the Bangor Dyslexia Test assesses areas of difficulty experienced by predominantly male dyslexics (see section 2.4). Vogel and Walsh (1987) maintained that "we have assumed in many instances that findings on male research samples generalize to all learning-disabled individuals when, in actuality, we have very scant information regarding the nature of learning disabilities in females" (page 143). As mentioned previously, females manifest relative strengths in the areas of verbal memory and rapid perceptual processing. Several of the ACID and Bangor Dyslexia Test subtests assess these skills. The possibility exists that deficits within these areas do not characterise dyslexia in females. Defining dyslexia according to a male profile and diagnosing it accordingly is likely to result in more males being identified than females. In this instance, the assessment process is contributing to uneven sex ratio within dyslexic populations.

Behavioural factors could also influence the sex ratio of dyslexic samples through what is referred to as a referral bias. Referral bias theory dictates that an equal number of males and females experience dyslexia, but relatively more attention is drawn to male cases because males in general, and especially males attempting to contend with academic failure, are more disruptive than females. It is the disruptive behaviour of males that brings them to the attention of the class teacher and is consequently responsible for their referral to special education services. In this instance it is behaviour, rather than academic proficiency, that determines which children are referred for assessment.

Finally, social factors could influence the number of males and females identified as dyslexic. The somewhat dated possibility exists that greater importance is placed on the development of literacy skills of males, whose prospects are more professional than those of females who "can always get married" (Thompson, 1990, page 26). Research suggests that cultural stereotypes which promote reading as more important for males than females result in reduced sex differences (McGuinness, 1981).

It is not within the scope of the current research to address biological or social/cultural factors. Instead, the focus of the current research is on the cognitive and behavioural differences that exist between dyslexics, non-dyslexics, males and females. The research addresses the extent to which the assessment process, from initial referral to formal diagnosis, contributes to the high proportion of males within dyslexic populations. The manner in which sex and dyslexia interact to influence responses to different methods of remedial instruction is also investigated. The possibility that dyslexic symptoms are qualitatively and/or quantitatively different between males and females is investigated, in order to determine whether sex differences can account for any of the variability observed between dyslexics. The potential importance of sex differences to the diagnosis, remediation and ultimate understanding of dyslexia is described by Geschwind (1981, Forward page xiv) who wrote as follows:

"The arguments for studying the problem are powerful ones. In the first place, this type of investigation can have a useful impact on research. For example, the strikingly uneven proportion of males and females raises the possibility that the nature of dyslexia may not be uniform and that different retraining techniques may be necessary. Furthermore, the unequal sex ratio can suggest research approaches that may lead to better knowledge of the biological substrates of dyslexia and therefore lead to better prevention or treatment".

2.2 STUDY I: The Referral Bias Hypothesis

2.2.1 Introduction

The first section within this chapter examines the extent to which behavioural factors are responsible for the increased incidence of dyslexia in males. In this instance the greater number of male dyslexics is attributed to behavioural, rather than cognitive, factors. For example, the possibility exists that an equal number of males and females experience dyslexia, but due to differences in the way the sexes respond to dyslexia on an emotional/behavioural level, relatively more attention is drawn to male cases. This phenomenon is known as a referral bias and is linked to the way dyslexics are referred for assessment.

Males tend to be referred for assessment and remedial programmes more often than females (Koppitz, 1975) with approximately 75% of the learning disabled population being male (McGinness, 1985; Lerner, 1993). For children, the classroom teacher is the most common referral agent (Kavale and Reese, 1992) and research suggests that it is at this stage of the assessment process that a bias comes into operation. Flynn and Rahbar (1994), in a longitudinal study of reading development, found that the ratio of males to females experiencing reading difficulties was reasonably equivalent when reading failure was identified by poor performance on a standardised measure of reading ability; however, males outnumbered females by 2:1 in teacher identified reading disabled groups. Similarly, Vogel (1990) cites the findings of Mirkin (1982) who identified a 15% increase in male referrals when a teacher referral system was used as apposed to performance on measures of reading, spelling and written expression.

Wadsworth et al (1992) examined the gender ratios within five independent studies of reading disabled children. Only in the three clinic based or referred populations was there an excess of males. Within the research-identified samples the ratio of males to females was approximately 1:1. Similar findings where identified by Shaywitz et al (1990) who found that the ratio of males to females derived from research-identified populations, as opposed to school-identified populations, was virtually identical (1.2 to 1).

Mellard and Byrne (1993) examined the number of males and females receiving learning support in 103 community colleges in California. These authors identified a 4% excess of male students in learning disabled programmes. This excess is minimal in relation to the prevalence rates of males reported in samples of learning disabled children (see Finucci and Childs, 1981). Mellard and Byrne (1993) suggested that differential referral agents could potentially explain the more equivalent sex ratios in adult/student populations of poor readers. For example, students tend to refer themselves for support whereas children are referred by their teachers, a process which, may result in more male referrals.

There are several mechanisms which could potentially be responsible for this referral bias. Firstly, believing that dyslexia is predominantly a male condition could influence teacher's perceptions of the disorder and consequently decisions to refer (Anderson, 1997). An alternative explanation places considerable emphasis on the child's overt behaviour within the classroom.

A finding reported by numerous researchers suggests that it is the disruptive behaviour of males (Anderson, 1997; Ysseldyke et al, 1983; Berry et al 1985) that results in their referral to special education services. Phipps (1982) investigated referrals within a single school district and found that 83% of male referrals were the result of behavioural problems, whilst 65% of female referrals were the result of academic problems. Phipps (1982) concluded, in accordance with Mirkin (1982, cited in Vogel, 1990), that it is disruptive behaviour rather than academic failure that determines referral. Disruptive children (perceived predominantly as male) are more likely to be referred for assessment and placement in special education which Phipps (1982) referred to as the "dumping ground for boys perceived as conduct problems" (page 430). According to Sadker and Sadker (1994) and Leinhardt, Seewald and Zigmond (1982), girls behave differently in the classroom situation to boys, demonstrating behaviours that are more conducive to a productive learning environment. Specifically, they are quieter, more passive and conforming.

Shaywitz et al (1990) maintained that boys in general tend to be rated by their teachers as more disruptive, inattentive and lacking in the proficiency demonstrated

by their female peers on tasks involving language, even though their actual ability and achievement did not differ. It is argued that these behavioural characteristics are prevalent within the predominantly male, school-identified population of dyslexics, and are the reason for more male referrals. According to Shaywitz et al (1990), it is behaviour, rather than proficiency in literacy skills, that determines which children are referred for assessment, the perceived disruptiveness of males representing the only reason for the increased male presence in remedial settings. The idea that, in general, males are more disorderly than females is thus fundamental to referral bias theory and will be addressed within the current study. Furthermore, if referral is a response to disruptive behaviour which consequently characterises children in remedial settings (Shaywitz et al (1990), then individuals attending a specialist school, who have been subject to a referral bias, should be rated as more disruptive than individuals within a non-selected school.

A sex difference may also exist within the personality characteristics that occur as a consequence of dyslexia, what Richardson & Stein (1993) referred to as the 'secondary effects' of dyslexia. In this instance, behavioural problems are considered secondary responses to primary difficulties with literacy acquisition (Thomson, 1990). For example, a dyslexic who perceives him or her self as failing academically could potentially exhibit a number of emotional or behavioural responses to that perceived failure.

Burns (1982), Lawrence (1987) and Huntington and Bender (1993) postulated that a relationship existed between poor academic performance and self-esteem. Gjessing and Karlsen (1989), Rosenthal (1973) and Thomson and Hartley (1980) found that dyslexic children demonstrated reduced self-esteem relative to non-dyslexic children, possibly as a response to their experiences in mainstream schooling and, in particular, their relationship with 'significant' teachers (Burns, 1982). The development of a positive self-concept requires feelings of "acceptance, competence and worth" (Riddick, 1996 page 34). Children with learning difficulties (including dyslexia) often perceive themselves as less respected and significant relative to their academically competent peers and view their work as less valued (Fairhurst and Pumfrey, 1992, cited in Riddick, 1996).

Dyslexic children can become conditioned into a self fulfilling, downward spiral of learned helplessness (Chapman et al, 1984) and subsequently "expect to fail". They feel they have no control over their academic lives and their self-concept suffers. They demonstrate minimal confidence in their own abilities attributing success to external factors and failures to their own perceived incompetence (Butkowsky and Willows, 1980).They give up more readily and respond less well to failure (Riddick, 1996). Battle (1990) maintained that once a certain level of self esteem establishes itself, it becomes hard to challenge and consequently endures over time.

The interaction of academic failure with self esteem can manifest in different ways. For example, retarded readers are reported as more likely to experience behavioural and emotions problems (Tansley and Panckhurst, 1981; Gentile and Macmillan, 1987; Hinshaw, 1992; Huntington and Bender, 1993). Thomson (1990) refers to 'over' and 'under' reactions. Under reaction describes the child who is so discouraged and vulnerable that they become extremely anxious and depressed. School represents a considerable source of distress resulting in tears and emotional fatigue. These individuals attempt to cope with their academic despair and humiliation by becoming quiet, withdrawn and invisible within the class. The low self opinion of these children "generalizes to all aspects of their lives where they consider themselves failures, dunces, and generally useless" (Thomson, 1990, page 23). Over reaction is a form of overcompensation. In this instance, anxiety is masked by attempts to gain popularity or acceptance by disruptive behaviour. Thomson describes a scenario where bad behaviour leads to aggression, steeling, truancy, a lack of respect and hostility towards authority, culminating potentially in delinquency. Riddick (1996) also cites the findings of several studies that indicate a progression from inattentiveness and restlessness to conduct disorders during the primary school years.

Although Thomson (1990) depicts extreme circumstances, several European studies have identified a high frequency of dyslexia in prison populations (Daderman and af-Klinteberg, 1997). Rasmussen, Storsaeter and Levander (1999) found that a considerable proportion of the Norwegian male prisoners they studied reported a range of problems including ADD and dyslexia. Jensen, et al (1999) also

investigated the occurrence of dyslexia in Swedish prisons, diagnosing 41% of their sample as dyslexic. This group was characterised by paranoid and avoidant personality disorders, anxiety, suspicion and a reduced degree of socialization. Finally, Snowling et al (2000) found that 38% of the young offenders incarcerated in an English institution exhibited phonological deficits.

The under and over reactions could potentially reflect the disparity between the manner in which males and females deal with the emotional consequences of academic failure. A male who is experiencing difficulties may endeavour to hide his perceived failure in a display of indifference and disruptive behaviour, thus bringing himself to the attention of the teacher. Girls conversely deal with reductions in self-confidence and esteem by shying away from class activities, doing their utmost to avoid unwanted notice, failing quietly. Naiden (1976) maintained that the "low achieving boy shows his frustration in more overt ways than the low achieving girl. The low achieving girl does not become a behaviour problem as often as the low achieving boy" (page 443, cited in Anderson, 1997, page 155). Bruck (1985), Spreen (1987, cited in Riddick, 1996) and Hales (1994) found that adolescent and adult dyslexic females suffered from withdrawal, anxiety and depression, whilst Richardson and Stein (1993) identified an increased incidence of emotional conflict, worry, mood swings, anxiety, frustration and low self esteem in adult dyslexic males. The absence of these symptoms in dyslexic females led the authors to suggest that dyslexic males experience increased pressure regarding academic achievement.

Smart, Sanson and Prior (1996) found that two thirds of boys with reading problems also manifest behaviour problems compared to only one third of girls. However, these authors argued that reading difficulties did not result in behaviour problems, rather that the behavioural problems exacerbated the reading difficulties. Generally, emotional/behavioural difficulties are seen as a consequence of dyslexia (Working Party of the Division of Educational and Child Psychology, 1999); however, the relationship "between reading and behavioural difficulties is a complex one, which will probably reveal multiple causation and interactional effects" (Riddick, 1996, page 46).

Rather than a sex difference in general behaviour, in this instance reading failure interacts with sex to produce different effects in males and females. If this is the case, it is hypothesised that the relationship between reading and disruptive behaviour should be larger for males than females, and the relationship between reading and measures of withdrawal and anxiety should be larger in the case of females than males.

In summary the current study aimed to investigate the following hypotheses:

1.   Within a non-selected school, males in general will be rated as more disruptive and badly behaved than females.

2.   Individuals within a specialist school will on average be rated as more disruptive than individuals within a non-selected school.

3.   The relationship between reading and behaviour will be larger in a specialist school than in a non-selected school.

4.   Within a specialist school, the relationship between reading and disruptive behaviour will be larger in the case of males than females and the relationship between reading and measures of withdrawal, anxiety and low self esteem will be larger for females than males.

2.2.2 Measures

Behaviour and personality were assessed by the Strengths and Difficulties Questionnaire SDQ (Goodman, 1997). This is a "brief behavioural screening questionnaire that provides balanced coverage of children and young people's behaviours, emotions and relationships" (Goodman, 1997). The questionnaire assessed five behavioural scales: hyperactivity, emotional symptoms, prosocial behaviour, conduct and peer problems. Each scale was assessed by five questions.

Class teachers were required to individually rate the children within their class on 25 statements. Responses were scored as 'not true', 'somewhat true' or 'certainly true'. Whereas 'somewhat true' consistently represented a score of 1, 'not true' and 'certainly true' were scored as zero or two depending on how the statement was worded. For example, on the hyperactivity scale a rating of 'certainly true' on 'restless, overactive, cannot sit still for long' was afforded a score of two. Whereas the 'certainly true' on 'thinks things out before acting' would be scored as zero as it is a negative indicator of hyperactive behaviour.

For the four scales that assessed difficulties, the higher the score (out of a maximum of ten) the greater the difficulties. The sum of these four scales represented the measure of total difficulties (out of a maximum of 40). The index of prosocial behaviour was not included within the total difficulties score and in this instance the lower the score the greater the difficulties. Scores on each scale and the total difficulties score were then graded as normal, borderline or abnormal on the basis of 'bandings' within which 80% of children would be considered normal, 10% borderline and 10% abnormal (Goodman, 1997).

Reading was assessed by the single word reading subtest of the Wide Range Achievement Test (WRAT). Subjects under eight completed the letter reading section which constituted the naming of 15 letters. The word reading section required subjects to pronounce 42 words of increasing complexity. The test was discontinued after 10 incorrect responses and/or omissions. Individuals (over eight years old) who failed to score five correct responses on the word reading section were required to complete the letter reading section. The number of words pronounced correctly (plus the appropriate number of points awarded for letter reading) represented the subject's single word recognition score out of a maximum of 57. A standard score with a mean of 100 and a standard deviation of 15 was then derived on the basis of age based norms.

2.2.3 Subjects

Specialist School: The specialist school sample consisted of the Junior classes (Forms I to IV) of a private, primary school in East London. The school was closely associated with a Dyslexia Centre that was located on the same premises. The sample consequently consisted of children from the local area and dyslexics who attended the school to facilitate access to the Centre. It is possible, therefore, that a referral bias was already in operation within the sample, in that certain individuals had been identified as dyslexic and directed to the school accordingly.

Ninety-one children (52 males, 39 females) with a mean age of approximately 9 years, 4 months (range 7.3 to 11.3) were included in the study. Information gathered from the school's special needs register indicated that 28 children (18 boys and 10 girls, representing a ratio of approximately 2 to 1) were diagnosed dyslexics. In addition, the sample contained three dyspraxic males, one of whom also suffered from dysphagia. Two males and one female experienced emotional / behavioural difficulties (EBD), whilst two other girls had speech and language difficulties. One male and one female had general learning difficulties (GLD), the male in conjunction with social communication difficulties. It was noted that one girl had a premature birth, whilst another suffered from a growth disorder. An additional female subject suffered from Pervasive Developmental Disorder (Aspergers with selective mutism).

The ratings of males and females from the specialist school were compared on all the SDQ scales and WRAT reading, the results of which are displayed in Table 2.1. For prosocial behaviour, a higher score depicts favourable behaviour, for the other SDQ scales the converse applies.

54

Table 2.1: Mean ratings for males and females from the specialist school (standard deviations in brackets) on the six SDQ scales and on WRAT reading. Statistical comparisons (Independent Samples t tests) are also displayed.

	Males (N=52)	Females (N=39)	t-test (df=89)
Prosocial Behaviour out of 10	7.06 (2.51)	7.97 (2.23)	-1.808 (p=0.074)
Hyperactivity* out of 10	4.60 (2.89)	1.85 (2.22)	5.139 (p<0.001)
Emotional Symptoms out of 10	2.04 (2.25)	2.31 (2.27)	-0.563 (p=0.575)
Conduct Problems* out of 10	1.58 (2.06)	0.74 (1.19)	2.428 (p=0.017)
Peer Problems out of 10	1.58 (1.92)	1.82 (1.85)	-0.608 (p=0.545)
Total Difficulties out of 40	9.75 (6.46)	6.72 (5.03)	2.429 (p=0.017)
WRAT Reading Standard Score mean=100	103.08 (16.58)	108.15 (15.59)	-1.482 (p=0.142)

*For hyperactivity and conduct problems, equal variance not assumed in the analysis.

None of the mean ratings fell within the 'abnormal' or 'borderline' banding as described by the SDQ manual. Males were rated as significantly more hyperactive and as having more conduct problems than females and consequently showed a significantly higher index of total difficulties. Males showed lower prosocial ratings although this only approached significance. The ratings pertaining to emotional symptoms and peer problems appeared reasonably equivalent. Females outperformed males on the measure of single word reading, although this difference was not significant.

Non-selected School: The non-selected sample came from a state school in the South East of England. None of the subjects had any known Specific Learning Difficulties. Ninety-four children (48 males, 46 females) with a mean age of approximately 9 years, 1 month (range 7.0 to 11.6) were included in the study.

The ratings of males and females from the non-selected school were compared on all the SDQ scales and WRAT reading, the results of which are displayed in Table 2.2. For prosocial behaviour, a higher score depicts favourable behaviour, for the other SDQ scales the converse applies.

Table 2.2: Mean ratings for males and females from the non-selected school (standard deviations in brackets) on the six SDQ scales and on WRAT reading. Statistical comparisons (Independent Samples t tests) are also displayed.

	Males (N=48)	Females (N=46)	t-test (df=92)
Prosocial Behaviour out of 10	6.56 (2.58)	7.72 (1.83)	-2.495 (p=0.014)
Hyperactivity out of 10	4.17 (2.83)	2.98 (2.38)	2.198 (p=0.030)
Emotional Symptoms out of 10	2.40 (2.78)	2.46 (2.51)	-0.111 (p=0.912)
Conduct Problems* out of 10	2.10 (2.08)	1.04 (1.40)	2.894 (p=0.005)
Peer Problems out of 10	1.81 (1.96)	1.41 (1.54)	1.093 (p=0.277)
Total Difficulties out of 40	10.69 (6.16)	7.87 (6.29)	2.194 (p=0.031)
WRAT Reading Standard Score mean=100	96.58 (10.26)	100.80 (9.07)	-2.109 (p=0.038)

*For conduct problems, equal variance not assumed in the analysis.

None of the mean ratings fell within the 'abnormal' or 'borderline' banding as described by the SDQ manual. Females were rated as demonstrating significantly more prosocial behaviour than the males. Males conversely were rated as significantly more hyperactive and as having more conduct problems than females. Males consequently showed a significantly higher index of total difficulties than females.

2.2.4 Procedure

Hypothesis 1: In order to assess hypothesis 1, the ratings of males and females from the non-selected school were compared on all the SDQ scales and WRAT reading. Results are displayed in Table 2.2. In accordance with the premise of referral bias theory, males were rated as significantly more disruptive than females. The females, however, significantly outperformed the males on the measure of reading ability.

Hypothesis 2: In order to assess hypothesis 2, mean SDQ scores for children attending the specialist and non-selected schools were compared using an Independent Samples t test. Results are shown in Table 2.3. For prosocial behaviour, a higher score depicts favourable behaviour, for the other SDQ scales the converse applies.

Table 2.3: Mean ratings for the specialist and non-selected schools (standard deviations in brackets) on the six SDQ scales and on WRAT reading. Statistical comparisons (Independent Samples t tests) are also displayed.

	Specialist (N=91)	Non-selected (N=94)	t-test (df=183)
Prosocial Behaviour out of 10	7.45 (2.42)	7.13 (2.31)	0.929 (p=0.354)
Hyperactivity out of 10	3.42 (2.94)	3.59 (2.67)	-0.405 (p=0.686)
Emotional Symptoms out of 10	2.15 (2.25)	2.43 (2.64)	-0.753 (p=0.453)
Conduct Problems out of 10	1.22 (1.78)	1.59 (1.85)	-1.369 (p=0.173)
Peer Problems out of 10	1.68 (1.88)	1.62 (1.77)	0.239 (p=0.811)
Total Difficulties out of 40	8.45 (6.05)	9.31 (6.35)	-0.940 (p=0.348)
WRAT Reading* Standard Score mean=100	105.25 (16.28)	98.65 (9.88)	3.323 (p=0.001)

*For WRAT reading, equal variance not assumed during the analysis.

The specialist and non-selected school samples did not differ significantly on any of the SDQ scales. If a referral bias had been in operation within the specialist school, it was hypothesised that the individuals within this sample would on average be rated as significantly more disruptive than the individual's from the non-selected school. This was not found to be the case. The only difference identified between the groups was on WRAT reading. Despite the high number of dyslexics within the specialist sample, this group significantly outperformed the non-selected school on the reading task, although scores from the specialist school were more variable, ranging from 54 to 140. It should be re-iterated that this sample consisted of approximately two thirds children from the local area and one third dyslexics.

Hypothesis 3: In order to assess hypothesis 3, the correlation between reading scores and SDQ ratings were calculated for both the specialist and non-selected schools.

Table 2.4: Correlations between reading ability and the SDQ scales for children from the specialist and non-selected schools.

	Single Word Reading (Standard Score)	
	Specialist (N=91)	Non-selected (N=94)
Prosocial Behaviour	-0.079	0.243*
Hyperactivity	-0.324**	-0.334**
Emotional Symptoms	-0.112	-0.246*
Conduct Problems	-0.116	-0.253*
Peer Problems	-0.008	-0.204*
Total Difficulties	-0.239*	-0.336**

** Correlation significant at the 0.01 level

* Correlation significant at the 0.05 level

In accordance with the idea that behavioural/emotional problems co-occur with academic difficulties (including poor reading) it was hypothesised that the relationship between reading ability and performance on the SDQ scales would be greater within the specialist school. This does not appear to be the case. Within the non-selected school, reading was significantly correlated with all the SDQ scales. Within the specialist school only hyperactivity and the measure of total difficulties were significantly correlated with reading ability. These correlations were small in both cases.

Differences within the specialist school were examined in more detail by dividing the specialist school sample into two groups consisting of 27 dyslexics (17 boys and 10 girls) and 50 non-dyslexics (28 males and 22 females). One male was excluded from the dyslexic group as English was not his first language. Other individuals included on the school's special needs register for difficulties other than dyslexia were also excluded.

The mean SDQ ratings and reading performance of dyslexics, non-dyslexics, males and females were compared. Mean scores obtained by dyslexic males and females and non-dyslexic males and females are shown in Table 2.5

Table 2.5: Mean ratings for dyslexics (males and females) and non-dyslexics (males and females) from the specialist school (standard deviations in brackets) on the six SDQ scales and on WRAT reading.

	Dyslexics		Non-dyslexics	
	Males (N=17)	Females (N=10)	Males (N=28)	Females (N=22)
Prosocial Behaviour out of 10	7.00 (2.29)	7.60 (2.55)	6.89 (2.66)	8.27 (1.86)
Hyperactivity out of 10	5.65 (2.32)	2.60 (0.84)	4.04 (3.05)	0.73 (0.98)
Emotional Symptoms out of 10	2.24 (2.02)	3.50 (3.03)	1.57 (2.01)	1.68 (1.67)
Conduct Problems out of 10	1.47 (2.18)	1.10 (1.29)	1.64 (1.97)	0.55 (1.14)
Peer Problems out of 10	1.41 (1.73)	1.70 (2.21)	1.43 (1.93)	1.68 (1.55)
Total Difficulties out of 40	10.76 (5.24)	8.90 (5.55)	8.68 (6.91)	4.64 (3.13)
WRAT Reading Standard Score mean=100	87.18 (12.47)	97.30 (11.91)	111.75 (12.86)	116.68 (12.05)

Two way analyses of variance were employed to investigate the interaction between the independent variables of group (dyslexic / non-dyslexic) and sex (males / females) and the mean rating on each SDQ scale and WRAT reading score.

For scales of prosocial behaviour, conduct and peer problems no main effects of group or sex or any interactions between them were identified (all $p > 0.05$). Contrasts pertaining to hyperactivity revealed both significant main effects of group (F=10.155, df=1 & 73, p=0.002) and sex (F=33.790, df=1 & 73, p<0.001). The dyslexics were more hyperactive (mean rating: 4.52, standard deviation: 2.41) than the non-dyslexics (mean rating: 2.58, standard deviation: 2.88) and males were more hyperactive than females (mean rating for males: 4.64, standard deviation: 2.88, mean rating for females: 1.13, standard deviation: 1.28). No significant interaction between group and sex was apparent (p=0.812).

A significant main effect of group was also identified on the emotional symptoms scale (F=5.945, df=1 & 73, p=0.017). The dyslexics were found to be more emotional than the non-dyslexics (mean rating for dyslexics: 2.70, standard deviation: 2.46, mean rating for non-dyslexics: 1.62, standard deviation: 1.85). There was no significant main effect of sex (p=0.181) or an interaction between group and sex (p=0.261).

The index of total difficulties revealed both significant main effects of group (F=5.542, df=1 & 73, p=0.021) and sex (F=4.796, df=1 & 73, p=0.032). Dyslexics had more total difficulties than non-dyslexics (mean for the dyslexics: 10.07, standard deviation: 5.33, mean for the non-dyslexics: 6.90, standard deviation: 5.88) and males (mean: 9.47, standard deviation: 6.36) had more total difficulties than females, (mean: 5.97, standard deviation: 4.42). No significant interaction between group and sex was apparent (p=0.422).

Significant main effects of group (F=52.107, df=1 & 73, p<0.001) and sex (F=6.113, df=1 & 73, p=0.016) were also identified for WRAT reading. Dyslexics were poorer readers than non-dyslexics (mean score for dyslexics: 90.93, standard deviation: 13.02, mean score for non-dyslexics: 113.92, standard deviation: 12.63) and males were poorer readers than females (mean score for males: 102.47, standard deviation: 17.41, mean score for females: 110.63, standard deviation: 14.93). No significant interaction between group and sex was apparent (p=0.397).

These findings suggest that males are considered to be more hyperactive than females who are, on average, better at reading than males. The non-dyslexics outperformed the dyslexics on the reading task and the dyslexics were more hyperactive and emotional than non-dyslexics, suggesting that these factors are related to dyslexia.

Hypothesis 4: In order to assess hypothesis 4, the correlation between reading scores and different aspects of the SDQ, were determined for males and females (dyslexics and non-dyslexics only) within the specialist school. These are displayed in Table 2.6 (columns headed total males and total females). No significant relationships were

identified between any of the SDQ scales and the reading ability of males. For the females a highly significant negative correlation was identified between hyperactivity and reading. It was hypothesised that the correlation between reading and SDQ items pertaining to disruptive behaviour (including hyperactivity), would be larger in males than females and that the correlation between emotional / social items and reading would larger in females than males. This did not appear to be the case, in fact, the results support the opposite.

Table 2.6: Correlations between reading ability and the SDQ scales for dyslexics, non-dyslexics, males and females within the specialist school.

	Single Word Reading (Standard Score)							
	Dyslexics			Non-dyslexics			Total Males (N=45)	Total Females (N=32)
	Males (N=17)	Females (N=10)	Total (N=27)	Males (N=28)	Females (N=22)	Total (N=50)		
Prosocial Behaviour	-0.004	-0.574	-0.151	-0.309	0.066	-0.114	-0.164	-0.038
Hyperactivity	-0.259	-0.208	-0.408*	0.131	-0.140	-0.055	-0.182	-0.511**
Emotional Symptoms	0.207	0.522	0.400*	-0.288	-0.364	-0.304*	-0.188	-0.213
Conduct Problems	0.153	0.462	0.167	-0.200	-0.415	-0.302*	-0.016	-0.235
Peer Problems	0.216	0.501	0.332	-0.167	-0.143	-0.140	-0.023	0.074
Total Difficulties	0.100	0.561	0.177	-0.130	-0.462*	-0.253	-0.154	-0.293

** Correlation significant at the 0.01 level
* Correlation significant at the 0.05 level

2.2.5 Discussion

The introduction described two possibilities whereby behaviour could result in a greater incidence of male referrals. The first of these maintained that males were rated as more disruptive than females and were consequently more likely to be referred for assessment even though the sexes did not differ academically. The second possibility suggested that males and females responded differently to academic failure, males becoming more disruptive and hence more likely to be referred than females who become withdrawn. In both instances it is the disruptive behaviour of males that is responsible for their increased referral rate; however, the second possibility assumes that this is a response to their learning difficulties.

Within both the non-selected and specialist school samples, males were rated as significantly more hyperactive, as having more conduct problems and consequently as having a significantly higher index of total difficulties than females. Females conversely, demonstrated more prosocial behaviour than males although this difference was only significant within the non-selected school. When the specialist school sample was reduced to include only dyslexics and non-dyslexics, males continued to be rated as more hyperactive and as having more total difficulties than females. In accordance with the premise of referral bias theory, males were rated as significantly more disruptive than females. However, in all three samples (e.g. the non-selected school, the specialist school and the reduced sample from the specialist school) males were significantly poorer readers than females. Although males were rated as having more behavioural problems they were also worse at reading. Either of these factors could be contributing to the increased number of male referrals.

When the total sample from the specialist school was compared to the sample from the non-selected school no differences were identified on any of the SDQ scales. If referral is a response to behaviour then individuals within the specialist school (a third of whom could have potentially been subject to a referral bias) should, on average have been rated as more disruptive than individuals within the non-selected school. This did not appear to be the case suggesting that referral is not necessarily a response to behaviour. However, the dyslexics within the specialist school were rated as significantly more hyperactive and emotional than the non-dyslexics within the

specialist school, suggesting that dyslexia is related to increased hyperactivity and emotional symptoms.

These results present as very mixed. In accordance with Shaywitz et al (1990), males were rated by their teachers as more hyperactive and as having more conduct problems than females. However, whereas the males and females within the Connecticut Longitudinal Study (CLS: Shaywitz et al, 1990) did not differ on measures of IQ or attainment (including reading), the males within the non-selected and specialist school samples were significantly poorer readers than the females. In this instance, both academic and behavioural factors distinguished between the sexes, whereas only behavioural factors distinguished between males and females within the Connecticut Longitudinal Study.

Shaywitz et al (1990) compared third grade poor readers identified as reading disabled by their schools (school/system identified), to poor readers identified by a research criteria (described in section 2.3.3). Shaywitz's school-identified poor readers, had a male to female ratio of approximately 2.2:1 and were found to differ from the remainder of the CLS sample (non-school identified) on measures of behaviour and activity. The school-identified poor readers also had significantly lower verbal and full scale IQs, and were poorer at reading and maths. The research-identified group of poor readers had a male to female ratio of approximately 1.4:1 and only differed from the non research-identified group (i.e. the remainder of the CLS sample) in terms of their weaker reading and mathematical ability.

Both Shaywitz et al (1990) and the current study investigated the effects of group and sex and the interaction between them on reading ability. Both studies (i.e. Shaywitz et al, 1999 and the current study) identified a main effect of group. Shaywitz et al's control groups outperformed their poor reader groups and the non-dyslexics in the current study outperformed the dyslexics. However, only the current study identified a main effect of gender on reading ability. The reading ability of the males was significantly poorer than that of the females. Shaywitz et al (1990) did not identify main effects of gender on reading ability.

The mean reading scores obtained by Shaywitz et al's (1990) school-identified reading disabled males was slightly higher than that obtained by their females (standard scores of approximately 88 and 84 respectively). The scores obtained by the research identified males and females were also very similar (standard scores of approximately 85 and 86 respectively). In contrast, the mean reading ability of the dyslexic males and females from the specialist school varied by approximately 10 standard score points. These groups were not directly compared during the analysis; however, this difference was just significant $p=0.049$. The mean reading ability of the dyslexic males was approaching one standard deviation below average (standard score of 87) and was similar to the scores obtained by Shaywitz et al. The dyslexic females, however, achieved a mean standard score of 97. The finding that dyslexic females outperformed dyslexic males is also inconsistent with the research reviewed by Vogel (1990), who suggested that before females were referred for assessment they had to manifest more severe literacy difficulties. If referral is a response to behaviour and dyslexic females (who are relatively well behaved) are only referred when their literacy is severely impaired, then the dyslexic females should have shown worse reading skills than the dyslexic males.

Shaywitz et al's (1990) argument that behaviour was responsible for referral was strengthened by the comparable reading scores obtained by their males and females. If the sexes do not differ on measures of literacy attainment it is conceivable that other factors (e.g. behaviour) could be contributing to the disproportionate number of males referred for assessment. Although comparisons between the specialist and non-selected school suggested that referral was not necessarily a response to behaviour, comparisons within the specialist school do not allow us to eliminate this possibility. For example, dyslexics were more hyperactive and emotional than the non-dyslexics, suggesting that these factors are related to dyslexia. These differing results could reflect the comparability of the specialist and non-selected schools. Perhaps it is better to compare individuals within the same institution who are subject to the same behavioural expectations. However, the response of individual teachers to disruptive behaviour differs considerably. In this instance, it is unlikely that between school differences would be any greater than differences between classes within the same school.

The second hypothesis concerned the extent to which academic problems result in secondary behavioural/emotional problems. Contrary to prediction the relationship between reading ability and behaviour appeared larger within the non-selected school compared to the specialist school. If behavioural/emotional problems were in some way associated with poor academic performance the relationship between reading ability and ratings on the SDQ should have been greater within the specialist school.

When the dyslexics and non-dyslexics within the specialist school were analysed separately, the results indicated that the dyslexics reading ability was related to hyperactivity and emotional symptoms. This is consistent with the finding that dyslexics were rated as more hyperactive and emotional than the non-dyslexics, and suggests that that these factors are related to dyslexia. However, whereas hyperactivity was negatively correlated with reading, emotional symptoms and reading were positively correlated. Contrary to prediction, the more emotional the dyslexic, the better their reading. Negative correlations were also identified between the reading ability of the non-dyslexics and emotional symptoms and conduct problems.

When the relationship between reading and behaviour was investigated for males and females within the specialist school no support was found for the hypothesis that males become more disruptive and females more withdrawn when they experience learning difficulties. Although males (dyslexic and non-dyslexic) were rated as more hyperactive and as having more total difficulties than females no significant relationships were identified between these factors (or any of the SDQ scales) and reading ability. For females (dyslexic and non-dyslexic), a highly significant negative correlation was identified between hyperactivity and reading, as hyperactivity increased reading ability decreased. The finding that hyperactivity is related to the reading ability of females but not males is contrary to the predictions of referral bias theory.

The correlations obtained by the non-dyslexic females (although non-significant) suggested that reading ability was negatively associated with emotional symptoms and conduct problems. Contrary to prediction, the opposite was identified for the

dyslexic females (although non-significant) the correlations suggested that reading ability was positively associated with emotional, conduct and peer problems and negatively associated with prosocial behaviour. In other words, the more unhappy, nervous, tearful or badly behaved the dyslexic female the better her reading. Whereas the more kind, considerate and helpful the dyslexic female the worse her reading. The direction of these relationships is contrary to the predictions of referral bias theory

The current results suggest that the dyslexics were more hyperactive and emotional than the non-dyslexics and that these behaviours were related to their reading ability (although not always in the predicted direction). However, it is unclear whether these behaviours are a response to reading failure or whether they in any way influence the referral process. Similarly, although males were more disruptive than females, they were also worse at reading and, on the basis of the current data, it is not possible to determine the relative contribution of either or both of these factors to the referral process.

2.2.6 Modifications and Future Research

The current findings suggested that both academic and behavioural factors could be contributing to referral. However, these findings are based on data obtained, in part, from children who had already been assessed as having dyslexia. This leads to the potential problem that the assessment process may mask any referral bias. That is, although UK teacher referrals may still be subject to bias, an assessment process that categorises children with behavioural problems differently (e.g., as having an Attention Deficit Hyperactive Disorder: ADHD, or an Emotional Behavioural Disorder: EBD) to those assessed as dyslexic may make the original bias difficult to detect. Future research may, therefore, consider studying any referral bias from an earlier point in the process of referral/assessment. This could be accomplished at the time of referral or prior to referral. For example, assessments of basic literacy attainment, behavioural problems and underlying cognitive facility (e.g., in areas of phonological processing or general IQ) at school entry could be followed by similar assessments at the start of each school year throughout the primary education of a

cohort of typical children. If this were accomplished across enough schools, the level of prediction of referral afforded by literacy attainment, behavioural problems and cognitive factors could be determined. This would also provide assessments of the level of variability explained by measures in the same year as referral and in years prior to referral. Problems that present as consistent over the years (e.g., literacy acquisition difficulties) may have to be accompanied by a change in other predictors (e.g., increased behavioural problems) to lead to referral, for example. If the referred cohort could then be followed to formal assessment, this would enable any influence of the assessment process on referral bias to be determined.

The extent to which behaviour and attainment predict the referral of different groups of children could also be investigated. This would allow an assessment of whether different factors predicted the referral of dyslexics compared to children with behavioural difficulties (e.g. ADHD or EBD). If a referral bias were in operation (i.e. it is behaviour that is responsible for referral) then, irrespective of the type of difficulty, all children would be referred on the basis of behaviour. However, if children with behavioural difficulties were referred because of their behaviour, but dyslexics were referred because of their academic difficulties, this would suggest that a referral bias was not in operation. The time of referral may also vary between these cohorts. One might expect early referral to be related to those with constitutional behavioural problems, whereas relatively later referral should be indicative of children with problems acquiring appropriate attainment levels in literacy.

Another factor to consider is the referral agent, as this does not necessarily have to be a teacher. Sometimes parents (herein meant to encompass parent/primary carer etc.) request assessments. As such, assessments that involve parental measures (e.g., interviews with parents determining their concerns about their child's behavioural and/or academic progress) would indicate the level at which referral by parents is influenced by behavioural and/or literacy attainment factors. For example, disruptive behaviour resulting from academic failure could manifest at home as well as at school (e.g. during homework sessions). This data would also facilitate comparisons between teacher and parent referral, i.e. is referral determined by similar factors in both cases.

Clearly, such studies were beyond the resources available to the current research project. However, the data obtained from the work presented in this thesis indicate that if a referral bias does exist, it is a much more complex process than might be inferred from the literature that advocates such a bias (e.g, Shaywitz et al, 1990).

2.3 Sex Differences and Diagnosing Dyslexia

2.3.1 The Assessment Process

The previous section examined the extent to which a referral bias could be contributing to the disproportionate number of males within dyslexic populations. The referral bias hypothesis suggests that due to disruptive behaviour more males are referred for assessment than females. The current studies seek to determine the extent to which the assessment process itself could account for the greater incidence of dyslexia in males.

Tansley & Panckhurst (1981, cited in Thomson 1990) maintain that "assessment should be (i) functional, i.e. to identify what is getting in the way of learning and (ii) descriptive, i.e. to identify what can be done to further learning" (page 144). According to Thomson (1990) a dyslexia assessment seeks to satisfy three avenues of enquiry. First, the assessment should provide a valid diagnosis of dyslexia (where appropriate) and ensure that the implications of this are fully explained. Debriefing is important for both adults and children and should be provided during follow up discussions, or via referral to other professionals. Explanations as to the nature of dyslexia help to avoid the stigmatism often associated with a disability label and, in some cases, allow the dyslexic to consider their perceived academic failure in a different context. As described in the previous section. dyslexia is often associated with considerable reductions in self esteem and self worth, which can potentially result in a number of emotional/behavioural difficulties. It is as important to address these secondary consequences of dyslexia as it is the primary academic implications.

The second purpose of an assessment is to determine the individual's current level of difficulty and how this is likely to interfere with access to the curriculum, or their ability to fulfil specific course requirements. Related to this is the idea of 'assessment of need'. This refers to the resources, tuition or concessions that the individual is likely to require. This is consistent with the third function of the assessment which is to detail the individual's relative strengths and weaknesses. This is of importance to diagnosis and the provision of support. For example, the presence or absence of depressed scores, on those aspects of cognition usually associated with dyslexia, is

instrumental to diagnosis. In addition, an understanding of the subject's cognitive profile can inform as to the appropriateness of remedial teaching strategies or study skills techniques.

2.3.2 Discrepancy Between Reading and IQ

Identification of underachievement in literacy skills represents an integral component of the diagnostic process and has played an important role in defining dyslexia. For example, the regression based discrepancy model of dyslexia, established in the 1970's, (Yule et al, 1974) was responsible for the distinction between general and specific learning difficulties. There are several different means of measuring discrepancy. For example, one potential method concerns the relationship between chronological age (CA) and reading ability. In this instance, a child is considered dyslexic if their reading age is significantly below there CA. However, there is no fixed threshold beyond which the level of discrepancy is considered significant and, even if one existed, this would fail to accommodate the changing relationship between reading ability and age (i.e. as age increases the correlation between age and reading decreases). In addition, this method of determining discrepancy cannot distinguish between general and specific learning difficulties. For example, an eleven year old with a reading age and an IQ age equivalent of nine would be regarded as a slow learner, whereas an eleven year old with an IQ equivalent of thirteen and a reading age of nine is underachieving specifically in reading. As both are two years behind in reading this discrepancy method would consider them identical.

An alternative approach concerns the degree of discrepancy between an individual's literacy levels and the literacy levels predicted by their general intellectual ability. Scores on attainment (e.g. reading and spelling) and ability tests (e.g. measures of intelligence) can be converted into standard scores (mean of 100 and a standard deviation of 15) or T scores (mean of 50 and a standard deviation of 10) and directly compared. According to the National Working Party's Report on Dyslexia in Higher Education (1999), a difference of 1 standard deviation is the minimum that can be considered significant (i.e. not caused by normal or chance variation). "The larger the difference in terms of standard deviation units (e.g. 1.5, 2 or greater), the

correspondingly greater can our confidence be regarding the statistical and educational significance of the observed discrepancy" (National Working Party's Report on Dyslexia in Higher Education 1999, page 99).

The potential problem with this approach is the assumption that attainment should equal ability. In other words, an individual with an IQ of 120 should achieve an equivalent standard score on a measure of reading ability. The correlation between reading and IQ, however, is not perfect, ranging from 0.3 to 0.7 (Stanovich, Cunningham & Feeman, 1984). IQ does not predict all of the variance in reading ability, providing instead an estimate of potential attainment, which is reasonably reliable providing scores fall within the average range. When extreme IQ scores arise (either below or above the average range), the relationship between IQ and reading becomes less robust as there is an increased probability that these scores were the product of factors other than true ability (e.g. chance or luck). If the individual were re-tested, their scores could potentially regress to the mean. Any predictions made on the basis of such extreme scores are subject to the same limitations. By overestimating IQ and using it to predict reading we may be overestimating reading. Actual reading ability is more likely to be closer to the mean, giving the impression of an ability / attainment discrepancy. If IQ is reassessed and regresses to the mean, the actual reading score might not be so inappropriate. As it is not considered good practice to re-administer IQ tests within a two year period, due to practice or carry-over effects, some tests control for regression to the mean statistically. For example, the WISC- III^{UK} (Wechsler, 1992), has standardised discrepancy tables that take regression to the mean into account. An estimate of the influence of regression to the mean is determined and a correction factor applied.

An additional discrepancy model, used to distinguish dyslexics from non-dyslexics, utilises a regression equation. In this instance, a regression equation based on the correlation between reading and IQ within a given sample is used to predict expected reading ability at varying levels of intelligence. The 'expected' and 'actual' reading scores are then compared and the level of discrepancy determined. Although this method accounts for the imperfect correlation between reading and IQ it can only be applied to the population from which it was derived (e.g. a large sample where the

correlation between reading and IQ is known). Additionally, as with comparisons of CA and reading age, there is not a single universally recognised difference between expected and actual reading that can be said to distinguish the dyslexic from the non-dyslexic. A number of researchers consider a discrepancy of one and a half standard deviations as important. For example, Miles et al (1998) used a regression equation and described a difference of one standard deviation as a 'moderate' discrepancy and anything above one and a half standard deviations as a 'severe' discrepancy. Similarly, Shaywitz et al (1990) defined individuals as reading disabled if their actual reading ability was over one and a half standard deviations below their expected reading ability. However, these may be considered arbitrary and other workers in the area will use different values (e.g. 1 standard deviation or 2 standard deviations).

The use of discrepancy models has been widely criticised in recent years. For example, Siegal (1989) and Stanovich (1994) maintained that there are no differences between poor readers with average to high intelligence and poor readers of low intelligence and that what was important was determining the underlying causes of literacy difficulties. Stanovich (1996) refutes the assumption that reading difficulties occurring within different IQ ranges are caused by different etiological factors; for example, that the reading problems experienced by individuals with general learning difficulties are caused by low intelligence, whilst the reading difficulties experienced by individuals with high IQs are caused by other factors. Stanovich (1996) goes on to contend that all reading difficulties are the result of a core phonological deficit. This represents a more descriptive definition of dyslexia, within which dyslexia is defined according to its observable deficits or symptoms (e.g. phonological processing difficulties). Genetic, neuroanatomical and cognitive studies are cited as demonstrating the equivalence of poor readers, with high and low IQs, with regard to word recognition and the processes that sub-serve it (e.g. phonological and orthographic processing). Stanovich (1996) concludes that "there exists no strong evidence that poor readers of high and low intelligence display marked differences in the fundamental cognitive and neurological processes that are the source of their reading difficulties" (page 160).

In contrast, other researchers (Coltheart and Jackson, 1998; Frith, 1999) suggest that poor performance on phonological processing tasks could be caused by a number of factors, including low intelligence, and does not necessarily reflect reading. For example, Thomson (2001) maintained that it is possible to find a slow learner whose phonological skills were in advance of their poor reading. Furthermore, distinguishing between high and low IQ poor readers may be important for remediation, with some practitioners arguing "that there is a great deal of difference between teaching a child who is a poor reader due to low ability and a dyslexic child" (Thomson, 2001, page 52). Dyslexics may differ from individuals with moderate learning difficulties on those aspects of intelligence that facilitate compensatory reliance on visual and/or semantic skills (Snowling, 2000).

Thomson (1990) maintained that dyslexia can occur anywhere on the IQ continuum, although it becomes hard to distinguish dyslexia from a global cognitive impairment once intelligence falls within the 'mentally retarded/defective' band (3 standard deviations below average).

2.3.3 Diagnostic Measures

As mentioned previously, the discrepancy criteria distinguishes between individuals with general and specific learning difficulties. In order to determine whether individuals with specific learning difficulties are dyslexic, a deficit criteria must also be met. The existence of a discrepancy between ability and attainment is considered obligatory but not sufficient in isolation for a diagnosis of dyslexia. Evidence pertaining to the existence of specific cognitive deficits is also required. According to the National Working Party's Report on Dyslexia in Higher Education (1999) "the principal difference between dyslexia and specific learning difficulty is that dyslexia presupposes the existence of certain cognitive deficits which are believed to underpin the condition" (page 99).

It has been suggested that the measures on which a diagnosis is made can influence the number of male and female dyslexics identified. For example, Shaywitz et al (1990) used the discrepancy criteria to identify poor readers (referred to as research

75

identified poor readers) in an epidemiological study (a study of incidence and distribution) of seven to ten year olds (mean age: 8.7, range 7.9 to 10.5) taken from the Connecticut Longitudinal Study (CLS). An individual was considered reading disabled if their actual reading ability was over one and a half standard deviations below their expected reading ability. Expected reading ability was derived from WISC-R (Wechsler, 1974) full scale IQ, using a regression equation based on the CLS sample. This subset consisted of 414 third graders, 199 boys and 215 girls. Eighteen boys (approximately 4%) and thirteen girls (approximately 3%) were determined to be reading disabled, prevalence rates that did not differ statistically. Similar results were obtained from a sample of second graders.

Miles et al (1998), in an attempt to 'operationalise' or 'sharpen' the concept of 'specific developmental dyslexia', employed both discrepancy and deficit criteria. Ten year old subjects, from the 10 year follow up of the British Birth Survey, were classified as moderate (actual literacy attainment 1 to 1.5 standard deviations below expected) or severe underachievers (discrepancy over 1.5 standard deviations). Expected scores were determined from an IQ composite score derived from the Similarities and Matrices subtests of the British Ability Scales (Elliott et al, 1979, 1983), using a regression equation. Greater emphasis was placed on underachievement in spelling as opposed to reading. Individuals who were found to be severely underachieving in spelling in isolation, or moderately underachieving in spelling and severely underachieving in reading, were considered to meet the discrepancy criteria. These underachievers where then classified according to their performance on clinical indices of dyslexia; in this instance the British Ability Scales recall of digits subtest, and the left/right orientation, months forwards and months reversed subtests from the Bangor Dyslexia Test (Miles, 1982, 1997). Three groups were identified according to their performance on these measures. Underachievers A were considered to be dyslexic as they scored a minimum of two positive or three intermediate indicators of dyslexia (see section 2.4) on the clinical tasks. This group had a male to female ratio of 4.5 : 1. Underachievers B (or the 'buffer' group) showed moderate difficulties on the clinical measures (e.g. one positive and one intermediate indicator or two intermediate indicators of dyslexia). This group had a male to female ratio of 2.27 : 1. Underachievers C comprised those individuals who

did not appear to be manifesting signs of dyslexia, scoring a maximum of one positive or one intermediate indicator on the clinical tasks. This group had a male to female ratio of 1.31 : 1. These figures demonstrate that when a clinical/deficit criteria is employed, more males than females are identified as dyslexic. Conversely, when a discrepancy criterion alone is used, the sex ratio is closer to 1:1, consistent with Shaywitz et al (1990).

In an additional analysis designed to be comparable with Shaywitz et al (1990), Miles et al (1998) used actual and predicted scores on a measure of reading comprehension (Edinburgh Reading Test) to identify a group of individuals underachieving specifically in reading. The ratio of males to females within this group was 1.63 : 1.

Taken together, the results led Miles et al (1998) to suggest that the way we define and diagnose dyslexia affects the number of males and females identified. They referred specifically to the distinction between specific reading retardation and dyslexia. Specific reading retardation is described as an 'isolated symptom' (Critchley 1981), the frequency of which is reasonably consistent across the sexes. Dyslexia, on the other hand, is a 'complex syndrome' (Critchley 1981), or constellation of symptoms, more commonly observed in males.

The following studies compare the performance of dyslexics, non-dyslexics, males and females on two of the most widely used and traditional methods of diagnosing dyslexia; the Bangor Dyslexia Test and the ACID profile obtained on the Wechsler scales. The aim was to investigate whether sex differences can account for any of the variability observed between dyslexics, and whether the assessment process is likely to affect the number of males and females identified as dyslexic.

2.4 STUDY II: The Bangor Dyslexia Test

2.4.1 Introduction

The Bangor Dyslexia Test (Miles, 1982, 1997) consists of a number of diagnostic items devised on the basis of an educated and experienced 'idea of dyslexia'. Through reviews of the literature, discussions with relevant professionals, dyslexics and their families, a battery of tests was devised that assessed known areas of dyslexic weakness or 'positive indicators of dyslexia' (Miles, 1993).

Inherent within the test is the notion of 'clinical feel'. This involves an analysis of test behaviour as well as ultimate test scores. The level of difficulty experienced by subjects is attributed significant diagnostic importance, as is a history of difficulties. Quantifiable and objective guidelines are provided for the scoring of clinical 'signs' or 'cues'. For example, hesitations, exclamations, the use of unusual strategies and behaviours indicative of working memory difficulties (e.g. requests for questions to be repeated, self prompting and re-orienting) are recorded by specific notation (e.g., *hes* represents a hesitation). On the basis of actual scores and clinical feel, performance on each subtest is described as either dyslexia positive (plus), dyslexia negative (minus) or intermediate/unclear (zero). For example, correct and fluent responses are scored as dyslexia negative, whilst incorrect responses or correct answers supported by the aforementioned clinical 'signs' are considered dyslexia positive. Intermediate/unclear responses are those that are "neither unambiguously dyslexia-positive nor unambiguously dyslexia-negative" (Miles, 1993, page 19).

Subtests included in the Bangor Dyslexia Test are follows.

1. Digits Forwards
2. Digits Reversed.
3. Left-Right (Body Parts)
4. Repeating Polysyllabic Words
5. Subtraction
6. Tables
7. Months Forwards

8. Month Reversed

9. b-d Confusion

10. Familial Incidence

Following completion of all subtests, an 'index figure' is determined that represents the total number of pluses out of ten. Miles (1993) describes this figure as a "guide to clinical diagnosis", which should be considered alongside other criteria (e.g. current literacy levels and evidence of an ability / attainment discrepancy).

Whether the number of pluses is considered clinically significant is determined by how incongruous it is relative to the child's age. For example, a ten year old of average intellect would not generally be experiencing difficulties reciting the months of the year or distinguishing between left and right. Although the number of pluses scored does not represent an index of severity (e.g. a child with 10 pluses is not necessarily more dyslexic than a child with 6), the more inconsistencies that occur the more likely the existence of dyslexia.

The aim of the current study was to investigate whether the items of the Bangor Dyslexia Test represented areas of weakness for dyslexic females compared to both non-dyslexic females and males (dyslexic and non-dyslexic). As many dyslexics and non-dyslexics who could be matched for sex (a factor not previously considered), IQ and age were extracted from Miles' (1993) sample.

2.4.2 Subjects

The current study used Miles' dyslexic and control data (Miles, 1993). Miles' data consists of 264 dyslexics. Of the 257 who were considered severely dyslexic, complete data is available for 233 (41 females, and 182 males, age ranging from 7.5 to 23.5). Miles' non-dyslexic sample consists of 132 subjects (67 females and 65 males, ages ranging from 7.5 to 18). Miles (1993) originally matched the non-dyslexics with a sub-group of the dyslexics (104 males, 26 females) for age and IQ grade. The non-dyslexic subjects only completed 7 out of the 10 items on the Bangor. Digits forwards, b/d confusion and familial incidence were omitted. Within

the current study index figures for both groups were consequently derived from the sum of the number of pluses scored on the remaining 7 items.

2.4.3 Procedure

Using the matched groups established by Miles (1993), 65 (out of the 104) dyslexic males were compared to the 65 non-dyslexic males. This sample remained equivalent with regard to age and IQ grade. The mean age of the dyslexics was 10.9 and 10.10 for the non-dyslexics (t=-0.058, df= 128, p=0.954). Miles (1993) derived a 'selected IQ' based on various items from the WISC (Wechsler, 1949, 1976), Terman-Merrill Test (Terman and Merrill, 1961) and in a few cases Ravens Advanced Progressive Matricies (Raven, 1965). The selected IQ was represented as one of six categories ranging from U (low average; e.g., a standard score of 90) to Z (highly superior; e.g., a standard score of 140+). For the current analysis, the categories of U to Z were coded as 1 through 6. A Mann-Whitney U test determined that the mean IQ ranking for the dyslexics and non-dyslexics did not differ significantly (N=130, U=2057.5, z =-0.266, p=0.791).

The mean number of pluses scored by dyslexic and non-dyslexic males on each subtest in isolation and combined (e.g. total number of pluses scored) were compared using an independent samples t-test. The poorer the performance the greater the number of pluses. Results are shown in Table 2.7

Table 2.7: The mean number of pluses scored by dyslexic and non-dyslexic males. Average scores (with standard deviations in brackets) and statistical comparisons are displayed.

	Mean no. of pluses		t-test (df=128)
	Dyslexic Males (N=65)	Non-dyslexic Males (N=65)	
Digits Reversed	0.63 (0.49)	0.40 (0.49)	2.685 (p=0.008)
Left-Right Body Parts	0.72 (0.39)	0.49 (0.43)	3.123 (p=0.002)
Repeating Polysyllabic Words	0.55 (0.42)	0.27 (0.39)	3.907 (p<0.001)
Subtraction	0.68 (0.38)	0.25 (0.40)	6.215 (p<0.001)
Tables	0.92 (0.24)	0.53 (0.48)	5.874 (p<0.001)
Months Forwards	0.68 (0.45)	0.24 (0.38)	5.993 (p<0.001)
Months Reversed*	0.92 (0.25)	0.40 (0.45)	8.215 (p<0.001)
Total No. of pluses (out of 7)	5.09 (1.15)	2.58 (1.41)	11.128 (p<0.001)

*Note: that the df value was 128 for all comparisons except those marked with an * where df=127. Case number 107, a non-dyslexic male did not complete months reversed. It is unlikely that this task was omitted due to a poor score on months forwards on which the subject's performance was rated dyslexia negative. Tables, months forwards, months reversed and the total, used statistical analyses that did not assume equal variance.*

As can be seen from Table 2.7, dyslexic males scored significantly more pluses than non-dyslexic males on all measures.

A similar analysis of the female data was conducted. Since the matched groups analysed by Miles (1993) consisted of only 26 females, the complete data set (e.g. 41 dyslexics and 67 non-dyslexics) was re-visited in an attempt to increase the number of females in the analysis. This led to 41 dyslexic females being matched to 41 non-dyslexic females for age (mean age for the dyslexics: 13.4, mean age for the non-

dyslexics: 12.9, t= -0.789, df= 80, p=0.432) and IQ grade (a Mann-Whitney U test determined that the mean IQ ranking for the dyslexics and non-dyslexics did not differ significantly N=82, U=836, z=-0.043, p=0.966). The mean number of pluses scored by the dyslexic and non-dyslexic females on each of the seven subtests, in isolation and combined (e.g. total number of pluses scored), were compared using an independent samples t-test. Again, poor performance is represented by a greater number of pluses. Results are shown in Table 2.8.

Table 2.8: The mean number of pluses scored by dyslexic and non-dyslexic females. Average scores (with standard deviations in brackets) and statistical comparisons are displayed.

	Mean no. of pluses		t-test (df=80)
	Dyslexic Females (N=41)	Non-dyslexic Females (N=41)	
Digits Reversed	0.85 (0.36)	0.46 (0.50)	4.038 (p<0.001)
Left-Right Body Parts	0.80 (0.33)	0.59 (0.42)	2.634 (p=0.010)
Repeating Polysyllabic Words	0.62 (0.43)	0.20 (0.31)	5.135 (p<0.001)
Subtraction	0.60 (0.41)	0.20 (0.31)	5.018 (p<0.001)
Tables*	0.90 (0.30)	0.60 (0.47)	3.444 (p=0.001)
Months Forwards*	0.26 (0.42)	0.08 (0.24)	2.385 (p=0.020)
Months Reversed**	0.60 (0.46)	0.21 (0.34)	4.336 (p<0.001)
Total No. of pluses (out of 7)	4.63 (1.05)	2.29 (1.36)	8.711 (p<0.001)

*Note that the df value was 80 for all comparisons except those marked with an * where df=79 and ** where the df=78. Case number 88, a non-dyslexic female did not complete tables, months forwards or months reversed. Case number 106, again a non-dyslexic female did not complete months reversed although performance on months forwards was rated as dyslexia negative. In all analyses, equal variance was not assumed.*

As can be seen from Table 2.8, dyslexic females scored significantly more pluses than non-dyslexic females on all measures.

The next stage in the analysis aimed to identify any potential interaction between group membership (dyslexic / non-dyslexic) and sex (male / female). The 130 males (65 dyslexics and 65 non-dyslexics) and the 82 females (41 dyslexics and 41 non-dyslexics) used in the previous analyses were compared. The dyslexics and non-dyslexics were equivalent in terms of age (mean age of the dyslexics: 11.9, mean age of the non-dyslexics: 11.7, t=0.437, df=210, p=0.637) and IQ grade (a Mann-Whitney U test determined that the mean IQ ranking for the dyslexics and non-dyslexics did not differ significantly N=212, U=5582, z=-0.083, p=0.934).

The males and females, however, were not matched for age or IQ. Females were found to be significantly older than the males (males: 10.10, females: 13.1, t= -5.907, df= 210, p<0.001). However, since age was taken into account during the scoring of the test (e.g. test performance is scored according to expectations based on age), this factor should not lead to differences between the sexes. A Mann-Whitney U test determined that the mean IQ ranking for the males and females also differed significantly (median IQ grade for males was 4 whilst the median IQ grade for females was 3, N=212, U=4522.5, z=-1.905, p=0.057).

A two-way analysis of variance was employed to investigate the interaction between the independent variables of group (dyslexic / non-dyslexic) and sex (male / female). The dependent variable was the total number of pluses. No significant interaction between group and sex was identified (F=0.239, df =1 & 208 p=0.626). This is presented graphically in graph 2.1. A highly significant main effect of group was identified (F=186.305, df=1 & 208 , p<0.001). Subsequent t-tests revealed that the dyslexics scored more pluses on every measure than the non-dyslexics (all p<0.001). A significant main effect of sex (F=4.353, df=1 & 208, p=0.038) was also identified. The relative performance of males and females on each subtest was subsequently investigated in order to examine this effect further.

Graph 2.1: The total number of pluses scored by the males (65 dyslexics and 65 non-dyslexics) and females (41 dyslexics and 41 non-dyslexics).
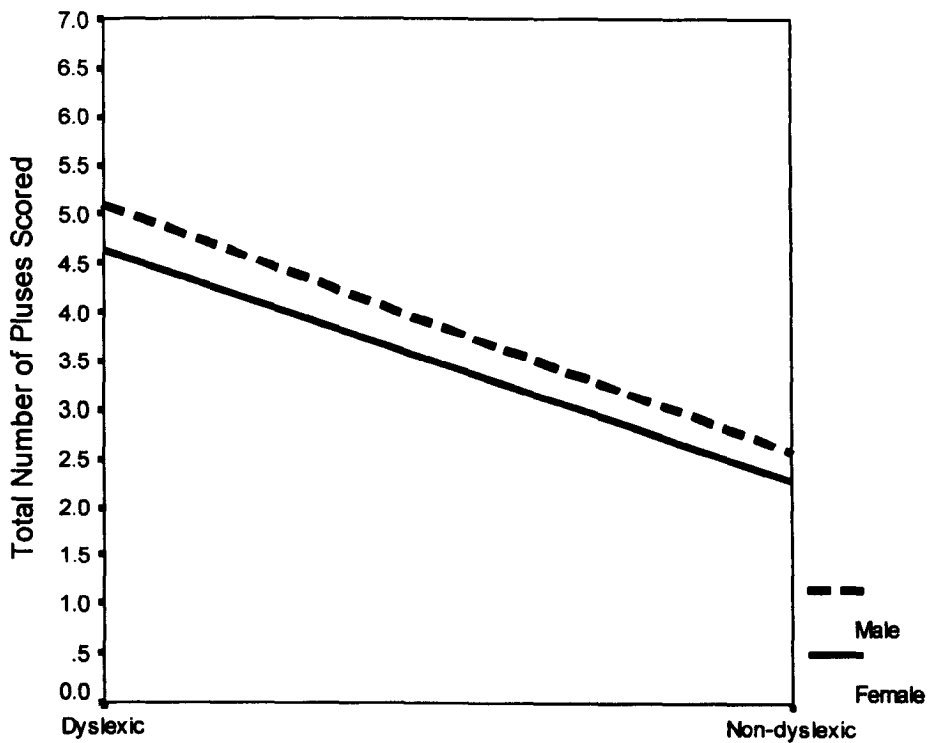
The mean number of pluses scored by males and females on each of the seven subtests of The Bangor Dyslexia Test were compared using independent samples t-tests. Again, weaker performance is represented by a higher number of pluses. Results are shown in Table 2.9.

Table 2.9: The mean number of pluses scored by males and females. Average scores (with standard deviations in brackets) and statistical comparisons are displayed.

| | Mean no. of pluses | | t-test (df=210) |
	Males 65 Dyslexic 65 Non-dyslexic	Females 41 Dyslexic 41 Non-dyslexic	
Digits Reversed	0.512 (0.50)	0.66 (0.48)	-2.085 (p=0.038)
Left-Right Body Parts	0.60 (0.42)	0.70 (0.39)	-1.580 (p=0.116)
Repeating Polysyllabic Words	0.41 (0.43)	0.41 (0.43)	-0.014 (p=0.989)
Subtraction	0.47 (0.44)	0.40 (0.41)	1.137 (p=0.257)
Tables*	0.73 (0.43)	0.75 (0.42)	-0.463 (p=0.664)
Months Forwards*	0.46 (0.47)	0.17 (0.35)	5.110 (p<0.001)
Months Reversed**	0.66 (0.45)	0.41 (0.45)	4.020 (p<0.001)

Note: that the df value was 210 for all comparisons except those marked with an * where df=209 and ** where the df=207. As with previous analyses, this was due to missing data within the non-dyslexic group (case numbers 107, 106 and 88 as described above). For digits reversed and months forwards, equal variance was not assumed in the analysis.

When the individual elements of the screening package were examined, the effect of sex was found to be specific to three subtests: digits reversed, on which females scored more pluses than males, and months forwards and reversed, on which males scored more pluses than females.

In order to rule out the possibility that these sex differences were attributable to the age and IQ differences between the male and female groups, the analysis was repeated on a sample that could be considered as matched in these respects. 62 dyslexics (31 males and 31 females) and 62 non-dyslexics (31 males and 31 females)

were derived from the original sample (233 dyslexics and 132 non-dyslexics) used by Mile's (1993) and matched for age and IQ grade.

Table 2.10: The average age in years (standard deviation in brackets), median IQ grade and mean total number of pluses scored (standard deviation in brackets) for dyslexic and non-dyslexic males and females.

	Dyslexics		Non-dyslexics	
	Males (N=31)	Females (N=31)	Males (N=31)	Females (N=31)
Mean age (years)	12.4 (2.78)	12.4 (2.76)	12.3 (2.66)	12.4 (2.74)
Median IQ grade	3	3	3	3
Total No. of pluses (out of 7)	5.18 (0.96)	4.71 (1.12)	2.61 (1.30)	2.24 (1.40)

Ages were compared using Independent Samples t-tests and IQ grades by Mann-Whitney U tests: Dyslexic males and females did not differ significantly in terms of age (t=0.080, df=60, p=0.936) or IQ grade (N=62, U=387, z=-1.352, p=0.176). Similarly, non-dyslexic males and females did not differ significantly with regard to age (t=-0.137, df=60, p=0.891) or IQ grade (N=62, U=458.5, z=-0.029, p=0.977).

A two-way analysis of variance was employed to investigate the interaction between the independent variables of group (dyslexic / non-dyslexic) and sex (male / female). The dependent variable was the total number of pluses scored. Again there was no significant interaction between group and sex (F=0.050, df=1 & 120, p=0.824), but a highly significant main effect of group (F=135.00, df=1 & 120, p<0.001). Subsequent t-tests revealed that the dyslexics scored more pluses on every measure than the non-dyslexics (all p<0.05). This analysis also identified a marginal main effect of sex (F=3.750, df=1 & 120, p=0.055). When this was investigated further (see Table 2.11) it became apparent that when age and IQ were controlled, females no longer demonstrated poorer performance on digits reversed and the significance of the difference on months reversed was greatly reduced. Even after controlling for

age and IQ, however, males continued to manifest poorer performance on the months forward subtest relative to the females.

Table 2.11: The mean number of pluses scored by males and females. Average scores (with standard deviations in brackets) and statistical comparisons are displayed.

	Mean no. of pluses		t-test (df=122)
	Males 31 Dyslexic 31 Non-dyslexic	Females 31 Dyslexic 31 Non-dyslexic	
Digits Reversed	0.66 (0.48)	0.63 (0.49)	0.373 (p=0.710)
Left-Right Body Parts	0.60 (0.41)	0.66 (0.39)	-0.787 (p=0.433)
Repeating Polysyllabic Words	0.45 (0.43)	0.39 (0.44)	0.826 (p=0.410)
Subtraction	0.45 (0.43)	0.37 (0.40)	1.074 (p=0.285)
Tables	0.76 (0.41)	0.77 (0.41)	-0.218 (p=0.828)
Months Forwards	0.36 (0.46)	0.19 (0.36)	2.370 (p=0.019)
Months Reversed*	0.61 (0.46)	0.48 (0.46)	1.672 (p=0.097)

Note that the df value was 122 for all comparisons except those marked with an * where df=120. A non-dyslexic female (case number 106) and a non-dyslexic male (case number 107) did not complete months reversed. It is unlikely that this task was omitted due to poor scores on months forwards on which both subjects were rated as dyslexia negative. For months forward, equal variance was not assumed in the analysis.

To further investigate the effect of sex on the Bangor Dyslexia Test, months forwards was removed from the screening package and the total number of pluses re-calculated accordingly (revised total). Again a two-way analysis of variance was employed to investigate the interaction between the independent variables of group (dyslexic / non-dyslexic) and sex (male / female). The dependent variable was the revised total number of pluses. No significant interaction between group and sex was

apparent (F=0.109, df =1 & 120, p=0.742). A highly significant main effect of group (F=122.567, df=1 & 120, p<0.001) was identified. The effect of sex was non-significant (F=1.536, df=1 & 120, p=0.218).

2.4.4 Summary

When the sexes were analysed separately significant differences were identified on all subtests of the Bangor Dyslexia Test. On every measure the dyslexics (both males and females) scored significantly more pluses than the non-dyslexics. When the interaction between group (e.g. dyslexic /non-dyslexic) and sex was investigated, main effects of group and sex were identified. The dyslexics scored significantly more pluses than the non-dyslexics and males scored significantly more pluses than females.

When the individual elements of the test were examined, the dyslexics were found to score significantly more pluses on all subtests compared to the non-dyslexics, whereas differences between males and females were confined to three subtests. Males scored fewer pluses than females on digits reversed (e.g. the males performed better than females) and more pluses than the females on months forwards and months reversed. Although the dyslexics and non-dyslexics within this analysis were equivalent in terms of age and IQ, the males and females were not matched on these variables. The females were approximately three years older than the males who demonstrated a higher median IQ grade. When these differences were controlled only a marginal main effect of sex was identified. Again, the total number of pluses scored by males was greater than that scored by the females. When the individual tests were examined, sex differences were restricted to the months forwards subtest, on which females continued to outperform males. When this subtest was removed and a revised total calculated accordingly, the effect of sex on the total number of pluses scored was non-significant.

The current analysis has identified a sex bias within the Bangor Dyslexia Test. Specifically, females outperformed males on months forwards. Although this difference was small (approximately 0.2 of a plus), it exerted an effect on the overall

index figure (total number of pluses). For example, dyslexic males scored half a plus more than dyslexic females. Although this difference was minimal, it could potentially interfere with the clinical diagnosis of dyslexia. It should be noted that individuals who perform very poorly or fail to score on months forwards are not required to attempt months reversed, which is subsequently scored as dyslexia positive, again potentially affecting the overall index figure. Such a small bias could result in a slight increase in the number of males considered at risk of dyslexia; however, it is unlikely that this would be as large as four to one. Months forwards distinguishes between dyslexics and non-dyslexics (both males and females) and providing the Bangor Dyslexia Test is used properly (e.g. considered along side literacy levels and evidence on an ability / attainment discrepancy, etc), the impact of this small bias should remain minimal.

2.4.5 Modifications and Future Research

The current study employed secondary data analysis in that it re-analysed Miles' (1993) data in order to investigate a new research question (e.g. possible sex differences on The Bangor Dyslexia Test). The use of secondary data means that the current researcher has no control over the quality of the data. Since secondary data analysis is only as reliable as the original data it is necessary to have an understanding of the strengths and limitations of the data being used. Additional issues concern the lack of familiarity with the phases of data collection and the appropriateness of the data with regard to the current research question. The procedures used to collect the data and produce the data set are extensively detailed in Miles (1993) as is the rationale for data collection (e.g. the data was designed to serve both descriptive purposes and to facilitate comparisons between dyslexics and non-dyslexics). Since Miles' data consisted of males and females secondary analysis did not present as an inappropriate means of investigating the current concept of interest e.g. sex differences on the Bangor. Although Miles' data was collected over 30 years ago during which time theoretical perceptions of dyslexia have altered the Bangor Dyslexia Test is still widely used as a screening package for dyslexia. Any potential sex differences are therefore of pertinence.

Another potential problem with Study II was the level at which the data was represented. Assigning a plus a value of 1, an ambiguous score a value of 0.5 and representing a minus as 0 suggests that the data is ordinal and non-parametric tests would have been a more appropriate means of comparing the performance of dyslexics/non-dyslexics, males and females. However, Mann-Whitney U-tests showed the same results as the t-tests performed.

Future research could consider potential sex biases on other dyslexia screening packages. For example, the Phonological Assessment Battery (PhAB: Frederickson, Frith and Reason, 1996), the Dyslexia Early Screening Test (DEST: Nicholson and Fawcett, 1996) and the Cognitive Profiling System (CoPS: Singleton, Thomas and Leedale, 1997).

Research included in a subsequent section of this thesis suggests that female dyslexics outperform male dyslexics on the spoonerisms subtest from the PhAB. Sex differences could also be apparent on other phonological awareness/discrimination tasks (e.g. detection of alliteration or rhyme) included within these three test batteries. According to Halpern (1997) females outperform males on tasks that require the speeded retrieval and manipulation of phonological information. A female advantage would therefore be predicted on rapid naming (included in PhAB and DEST) and verbal fluency (included in the PhAB) tasks. Indeed, the female advantage on verbal fluency tasks is reported to be one of the most significant sex differences favouring females (Kimura, 1999).

Whereas the sex differences literature predicts a female advantage on tasks that require the recall of verbal material or material that can be encoded verbally, results from the current study did not identify such a bias (e.g. no differences were identified between males and females on the digits reversed subtest from the Bangor Dyslexia Test, when age and IQ were controlled for). However, a female advantage was identified on a similar verbal memory task in a subsequent section of the thesis. Both DEST and CoPS include measures of verbal memory or verbal encoding, tasks on which females 'should' outperform males. DEST and CoPS also include measures of

associative memory and fine motor skills, which according to Halpern (1997, 2000) are additional measures at which females excel.

91

2.5 The Wechsler Intelligence Scale for Children

2.5.1 The Wechsler Scales and Dyslexia

Since its original publication by the Psychological Corporation in 1949, the Wechsler Intelligence Scale for Children (WISC) has become one of the most extensively used measures of intelligence in educational psychology. Modelled on the Wechsler-Bellevue Intelligence Scale (1939) (known in its revised form as the Wechsler Adult Intelligence Scale, WAIS), the WISC assesses 'general' intellectual functioning, through its examination of two ability dimensions, verbal and performance IQ. As discussed previously, the assessment of general cognitive ability facilitates comparisons between predicted and actual performance on measures of literacy and numeracy. It also provides an indication of the individual's specific strengths and weaknesses, which is of considerable importance for remediation and support.

The WISC was designed for administration to children between the ages of 5 to 15 (later versions assessed children aged 6 to 16) and consists of twelve subtests organised as follows:

Verbal Scale	Performance Scale
Information	Object Assembly
Similarities	Picture Completion
Arithmetic	Block Design
Vocabulary	Picture Arrangement
Comprehension	Coding
Digit Span	Mazes

The contrast between verbal and non-verbal ability was supported by Maxwell (1959) who identified two factors following a factor analysis of Wechsler's original standardisation sample. Maxwell's (1959) factors were labelled verbal intelligence and space performance. All verbal subtests loaded on the verbal intellectual factor as did coding, object assembly and block design. The space performance factor consisted of block design and object assembly (information and mazes were not included).

Cohen (1959) also reclassified Wechsler's standardisation sample, identifying five factors: verbal comprehension I and II, perceptual organisation, freedom from distractibility and a quasi specific factor. The subtests comprising these factors are shown in Table 2.12. Neville (1961) found that retarded readers performed poorly on subtests within Cohen's verbal comprehension I and freedom from distractibility factors. Neville (1961) concluded that "retarded readers do poorest in those subtests most nearly resembling school tasks and those requiring concentred attention" (page 197).

Subsequent attempts to extract what Turner (1997) referred to as "meaningful psychological dimensions" (page 56) from the WISC were conducted by Bannatyne (1971) and Kaufman (1975). See Table 2.12 (adapted from Vogel and Walsh, 1987). Based on Maxwell's (1959) content analysis, Bannatyne (1971) divided the WISC subtests into four factors labelled spatial, verbal conceptualization, sequential and acquired knowledge (tests comprising each are shown in Table 2.12). Dyslexics were reported to obtain their lowest scores on the sequential and acquired knowledge categories and their highest score on the spatial category. Their performance on verbal conceptualisation was described as 'moderate' (Thomson and Grant, 1979).

Rugel (1974) reviewed 25 studies concerning specific WISC subtest patterns in poor readers. Individual subtest scores from 22 samples were categorised into Bannatyne's categories. In general, poor readers received their lowest scores in the sequential category, whilst their best scores were on the subtests that comprised the spatial category. Rugel also investigated 11 samples where poor readers where compared with 'normal readers'. Poor readers were found to be superior to controls on the spatial ability subtests, slightly inferior in terms of their conceptualising ability and considerably weaker on sequencing ability (acquired knowledge was not included). Poor readers performed significantly worse than control groups on digit span in 6 out of the 11 samples, on coding in 5 out of 11 samples, on arithmetic in 10 out of 11 samples and on vocabulary in 4 out of 11 samples (information does not appear to have been included in the analysis).

Table 2.12: Different subgroupings of WISC subtests. Adapted from Vogel and Walsh (1987).

Cohen (1959)	Bannatyne (1971)	Kaufman (1975) WISC-R	WISC III (Wechsler, 1991)
Perceptual Organsiation	**Spatial**	**Perceptual Organsiation**	**Perceptual Organsiation**
Picture Completion	Picture Completion	Picture Completion	Picture Completion
Block Design	Block Design	Block Design	Block Design
Object Assembly	Object Assembly	Object Assembly	Object Assembly
		Picture Arrangement	Picture Arrangement
		Mazes	
Verbal Comprehension I	**Verbal Conceptualization**	**Verbal Comprehension**	**Verbal Comprehension**
	Comprehension	Comprehension	Comprehension
Similarities	Similarities	Similarities	Similarities
Vocabulary	Vocabulary	Vocabulary	Vocabulary
Information		Information	Information
Freedom From Distractibility	**Sequential**	**Freedom From Distractibility**	**Freedom From Distractibility**
Digit Span	Digit Span	Digit Span	Digit Span
	Coding	Coding	
Arithmetic	Arithmetic	Arithmetic	Arithmetic
		Information	
Verbal Comprehension II	**Acquired Knowledge**		**Processing Speed**
Comprehension	Information		Coding
Picture Completion	Arithmetic		Symbol Search
Vocabulary	Vocabulary		
Quasi-Specific			
Coding			
Picture Arrangement			

Kaufman (1975) identified a three-factor solution, inherent within the index scales that divide WISC-R (Wechsler, 1974). As shown in Table 2.12, verbal comprehension consisted of comprehension, similarities, vocabulary and information whilst perceptual organisation comprised all performance measures except coding. The third factor identified by Kaufman (1975) was labelled freedom from distractibility after Cohen's (1959) factor. This was made up of digit span, coding, arithmetic and information (the extent to which information loaded on this factor was dependent on the rotational technique used; i.e. a significant loading was identified only when an orthogonal varimax rotation was used). The factor structure of WISC-III (Wechsler, 1991) was divided still further with the addition of a fourth index score – processing speed (see Table 2.12). Subtests within perceptual organisation and verbal comprehension factors remained the same in WISC-III as in WISC-R (except for the exclusion of mazes from the perceptual organisation factor of WISC-III). In WISC-III, coding represents an index of processing speed together with symbol search (a new test unique to WISC-III). Arithmetic and digit span remain within the freedom from distractibility factor.

There is considerable convergence within the literature regarding the existence of a specific WISC profile associated with dyslexia. Extensive research has demonstrated that dyslexics consistently manifest relatively depressed scores on the information, arithmetic, digit span and coding subtests (Table 2.13 summarise some of these findings). This pattern of difficulties has been collectively referred to as the ACID profile. Several researchers (Belmont and Birch, 1966; Vargo et al, 1995) have also identified an AVID profile among WISC (Wechsler, 1949) and WISC-R (Wechsler, 1974) subtest scores. In this instance, a low score on coding is replaced by poor performance on the vocabulary subtest (arithmetic, information and digit span remaining consistent). Reference to Table 2.13 indicates that the ACID profile has been found more often than the AVID profile within reading disabled/dyslexic samples. A more recent addition is the SCAD profile which has been identified among WISC-III (Wechsler, 1991) subtest scores (Kaufman, 1994) and constitutes poor performance on symbol search, coding, arithmetic and digit span.

Table 2.13: Studies identifying ACID profiles in reading disabled (RD) / dyslexic (D) samples (column RD/D). Number of subjects in the RD/D group and comparison details are displayed. Age range or mean age and IQ range values for the RD/D group, followed by the ratio of males to females (♂ : ♀) within the RD/D group. An * indicates significantly poorer performance by the RD/D group relative to the Comparison on arithmetic (A), coding (C), information (I), digit span (DS) and vocabulary (V) subtests. The final row displays the total ratio of RD/D males to females.

Study	RD/D	No.	Comparison Details	Age Range (Mean)	IQ	♂:♀	A	C	I	D	V
Altus (1956)	RD	25	Relative performance across subtests (see section 2.5.4).	Elementary	Mean WISC FS IQ: 98.6	24 : 1	*	*	*		
Robeck (1960)	RD	36		6:11 to 13:9 (10:5)	Mean WISC FS IQ: 110	32 : 4	*	*	*	*	
Kallos et al (1961)	RD	37		9:0 to 14:0	WISC FS IQ: 90-109	37 : 0	*	*	*	n/a	
Klasen (1972)	D	488		6 to 18	Mean WISC FS IQ: 96	349:139	*	*		*	
Burks & Bruce (1955)	RD	31	11 good readers (5 boys, 6 girls)	Grades 3-8	WISC FS IQ: 90+	26 : 5	*	*	*		
Neville (1961)	RD	35	35 normal boys matched for age & IQ.	-	WISC FS IQ: 90+	35 : 0	*		*	*	
McLeod (1965)	RD	116	177 (100 boys, 77 girls) matched for age (IQ covaried)	12:4	WISC FS IQ: 80-120	85 : 31	*	*		*	*
Belmont & Birch (1966)	RD	90	49 normal boys matched for age & social class.	9:10	WISC FS IQ: 90+	90 : 0	*		*	*	*
Thomson & Grant (1979)	D	20	20 normal boys matched for age, IQ, (Socio-cultural background)	8:11 to 10:11	'Average' WISC FS IQ	22 : 0	*	*	*	*	*
Spafford (1989)	D	57	WISC-R stand. sample	9 to 12	WISC-R FS IQ: 90+	39 : 18	*			*	
Vargo et al (1995)	D	44	WISC-R stand. sample	7 to 16 (12:5)	'Average' WISC-R FS IQ	-	*	*	*	*	*
Total ratio of RD/D males to females.						3.7 : 1					

As shown in Table 2.12, the ACID tests load highly on Bannatyne's (1971) sequential and acquired knowledge factors, Cohen's (1959) and Kaufman's (1975) freedom from distractibility factor and the freedom from distractibility and processing speed factors within WISC-III. Interpretation of the freedom from distractibility factor is described by Kaufman (1975) as a "thorny problem" (page 139) as numerous behavioural and cognitive processes have been proposed to underlie performance on these tests. For example, concentration, distractibility, attention, anxiety, numerical and sequential ability, the ability to manipulate symbolic information and all component processes of working memory (phonological loop, visual-spatial sketch pad and the central executive). Although Turner (1997) presents evidence against the efficacy of the ACID profile (see Kavale and Forness, 1984), he maintains that poor index scores on freedom from distractibility and processing speed are indicative of "low level information processing difficulties [or] a learning difficulty of cognitive origin" (page 60).

A consideration of the individual tests that comprise the ACID profile follows, together with a discussion of the potential problems presented by each test for the dyslexic individual.

The information subtest assesses memory of purposely learned, factual material and is indicative of academic achievement. For this reason, Thomson and Grant (1979) considered it to be both "educationally and culturally biased" (page 109). The information subtest assesses general knowledge pertaining to recognized people, places, events and objects. Information processing deficits have been implicated as a cause of dyslexic's poor performance on this task (Swanson, 1987). For example, working memory limitations could result in information being poorly organised prior to transfer to long term memory. This lack of structure could lead to problems with the learning and retrieval of information. A second potential explanation of the dyslexic's poor performance on this task refers to their lack of reading experience. In this instance, the dyslexic's reduced exposure to print, stemming from their reading deficits, restricts their access to information, resulting in less opportunity to acquire the kind of general knowledge assessed by this subtest. Vogel and Walsh (1987) suggested that the information subtest required "not only the ability to comprehend,

integrate and retain factual information, but to be exposed to an enriched environment and adequate educational opportunity" (page 150).

Arithmetic assesses the subject's ability to manipulate numbers as concepts and/or the individual's arithmetical reasoning. Like information, the arithmetic subtest is also reliant on educational factors. Mathematical problems are presented verbally (except for the final items which are read by the subject) and must be resolved in working memory (the use of pen and paper is not permitted) within the designated time limit. Dyslexic's poor performance on this task could potentially result from memory or attentional deficits. For example, long term memory for mathematical principles is required, as is the ability to hold and manipulate task requirements/stimuli in working memory. In addition, short term memory deficits may have interfered with the dyslexic's ability to learn multiplication tables which could represent a potential disadvantage on this task. Finally, the arithmetic subtest is prone to elicit an anxiety response (Thomson and Grant, 1979) which may reduce the subject's ability to maintain prolonged concentration and attention.

Digit span requires subjects to repeat an arbitrary series of discrete numbers (presented verbally by the tester) either in the order presented or in reverse. It involves the rote memorisation (and manipulation in the case of digits backwards) of sequences over time. Dyslexic's poor performance on this task was traditionally attributed to a capacity constraint within working memory, sequencing or attentional problems. More recent interpretations, however, suggest that the Dyslexic's difficulties with this task are caused by the inefficient phonological encoding, and subsequent maintenance of phonological codes within the phonological loop (see Chapter 1).

Coding requires subjects to retain/process random associations between pairs of symbols and digits at speed. It is believed to assess processing speed, motor and visual co-ordination, attention and concentration. As such, it comprises a complex set of skills. Although it is included within the performance scale, coding has also been found to load highly on verbal factors (e.g., Maxwell, 1959). Thomson and Grant (1979) believed coding was related to verbal intelligence, as it required skills

fundamental to verbal and linguistic processes. They maintained that the coding task was comparable to written language it terms of its arbitrary and symbolic nature, and may consequently provide an indication of language processing efficiency. For example, the relationship between the visual form of a letter and its spoken equivalent is just as arbitrary as the associations between the symbols and digits within the coding task. Similar sentiments were voiced by Turner (1997) nearly 20 years on, who suggests that it is the "language-like character that poses difficulties for dyslexic children [and that] measures of speed may offer a summation of the efficiency of the whole language-processing system" (page 56).

2.5.2 Sex differences on the Wechsler Scales

Sex differences in general intellectual ability are considered minimal within non-dyslexic populations (Vogel, 1990; Kaufman, 1975). Maccoby and Jacklin (1974) reviewed 57 studies, 70% of which found males and females to be of equivalent full scale IQ. However, differences have been identified on some of the abilities from which composite IQs are derived. For example, a female superiority on vocabulary (WISC) and similarities (WAIS) has been identified (Maccoby and Jacklin,1974). Matarazzo (1972) found that adult females showed superior verbal subtest scores on the WAIS (Wechsler, 1955), whilst males were better at block design and picture completion. Similarly, McGuinness (1985) found that males outperformed females on the block design and object assembly subtests of WISC-R (Wechsler, 1974). Finally, females have consistently demonstrated superior performance on the coding/digit symbol subtest of WISC-R (Denno, 1982; Matarazzo, 1972) and WAIS (Vogel and Walsh, 1987).

Sex differences identified amongst the general population are not necessarily reflected within dyslexic populations, where males have been found to show higher verbal, performance and full scale IQs (Smith, Edmonds and Smith; 1989; Eno and Woehlke, 1980). The only similarity between dyslexic and non-dyslexic samples (other than the consistent male advantage on performance tests) is the female superiority on WISC-R coding (Smith, Edmonds and Smith, 1989; Vance, Singer and Engin, 1980; Ryckman, 1981; Levine and Fuller, 1972). However,

inconsistencies can be found in the literature. For example, Klasen (1972) tested a sample of 6 to 18 year old dyslexics (see Table 2.13) on the WISC (Wechsler, 1949) and the Wechsler-Bellevue Scale (Wechsler, 1939). Dyslexics were found to perform poorly on digit span, digit symbol / coding and arithmetic. Although this was the case irrespective of age and sex (e.g. on both WISC & Wechsler-Bellevue scales) dyslexic females achieved moderately higher scores on digit span in addition to digit symbol than their dyslexic male counterparts.

Subtest profiles may also be sex related. For example, Spafford (1989) found that the ACID profile was more representative of the performance of male dyslexics, whilst the AVID profile was evident in the pattern of scores achieved by female dyslexics. Dyslexic males outperformed dyslexic females on the vocabulary subtest whilst dyslexic females demonstrated superior performance on the coding subtest. The results described in Table 2.13 represent between group comparisons of dyslexics with the WISC-R (Wechsler, 1974) standardisation sample and does not reflect these within-group sex differences. A similar study by Vogel & Walsh (1987) compared the performance of learning disabled males and females on WAIS (Wechsler, 1955). The males significantly outperformed the females on picture completion, block design and information. Again, females significantly outperformed males on digit symbol (coding). The authors attempted to isolate the cause of the male advantage on the information subtest by comparing level of parental education and number/type of courses taken by the students at high school. The groups did not differ significantly on either of these measures. "Neither differences in the educational environment of the home nor exposure to information through formal instruction can account for the significant differences on the information subtest between LD females and LD males" (Vogel & Walsh, 1987, page 151). Vogel and Walsh (1987) went on to look at hierarchies of mean subtest scaled scores. For the males, the ACID subtests represented their lowest four scores. For females whose highest score was on digit symbol, the lowest four scores represented the AVID profile. When scores for Bannatyne's factors and the ACID tests were calculated and ranked, males achieved their highest factor score for spatial ability followed by conceptualising ability, acquired knowledge, the ACID factor and finally sequential ability. A different pattern emerged for the females who scored highest on conceptualising ability

followed by spatial ability, sequential ability, ACID and finally the acquired knowledge factor.

It is interesting to note that the research from which the ACID profile was derived was dominated by male samples. Within the research studies presented in Table 2.13 there are nearly four times as many males as females (3.7 to 1). With the exception of Spafford (1989) and Vargo (1995), these studies concerned the original WISC (Wechsler, 1949). Vargo (1995) refers to the work of Ackerman et al (1976), Dykman, et al (1973), Dykman et al (1980), Huelsman (1970), Smith, et al (1977), McManis et al (1978) and Sandoval et al (1988) all of whom identified statistically significant ACID profiles for dyslexic males on WISC-R (Wechsler, 1974). Since our current knowledge of dyslexic performance on the ACID tasks pertains predominantly to males, the possibility exists that female dyslexics may not demonstrate the same pattern of depressed scores. Innate cognitive sex differences could affect the manifestation of dyslexic symptoms, potentially contributing to the diversity observed within dyslexic samples. The possibility exists that dyslexia is quantitatively (i.e. varies in term of severity) and/or qualitatively (i.e. characterised by different cognitive deficits) different between the sexes. For example, the ACID pattern of difficulties may be more characteristic of male dyslexics whilst a different profile (perhaps the AVID profile, as suggested by Spafford, 1989) may be more representative of female dyslexics.

2.5.3 Aims of Research

The current investigation is divided into three studies to address three separate though related issues:

Study III investigated the extent to which the ACID and AVID subtests distinguished between dyslexic and non-dyslexic females.

Study IVa examined the relative performance of male and female dyslexics on WISC-III^{UK}. Specifically, performance on the ACID, AVID and SCAD tests were investigated in order to determine whether these profiles continued to describe the

performance of dyslexic males and to investigate the extent to which they represent the performance of dyslexic females.

Finally, Study IVb examined the relationship between the ACID, AVID and SCAD factors and various measures of literacy attainment. The aim was to determine whether the ACID, AVID and SCAD factor scores and/or the individual subtests of which they were comprised, predicted variability in dyslexic's reading, spelling and phonological processing.

2.6 STUDY III: Comparison of Dyslexic and Non-dyslexic Females on the ACID and AVID Tests.

2.6.1 Introduction

A wealth of literature exists documenting the poor performance of dyslexic males on the ACID and AVID subtests of the WISC (Wechsler, 1949) and the WISC-R (Wechsler, 1974) (see Table 2.13). These studies included those where, the dyslexic's performance was contrasted against the WISC's standardisation sample (Spafford, 1989; Vargo et al, 1995). In others comparisons were made between the ACID/AVID subtests and the remaining subtests. For example, Klasen (1972) and Robeck (1960) compared performance on the ACID/AVID subtests to the mean of all subtest scores, whilst Altus (1956) and Kallos et al (1961) examined significant differences between subtest means. Finally, five of the studies detailed in Table 2.13 (Burks and Bruce, 1955; Neville, 1961; McLeod, 1965; Belmont and Birch, 1966; Thomson and Grant, 1979) compared the performance of dyslexics to a comparison group of non-dyslexics. These latter studies determined that samples consisting of predominantly male dyslexics performed significantly worse than comparison groups (consisting of predominantly male non-dyslexics) on three or more of the ACID/AVID tests.

The ability of the ACID profile, and to a lesser extent the AVID profile, to distinguish between dyslexic and non-dyslexic males is therefore well documented. What has yet to be determined is the extent to which the ACID/AVID tests distinguish between dyslexic and non-dyslexic females. To this end, the present study investigated the relative performance of dyslexic and non-dyslexic females on the arithmetic, coding, information, digit span and vocabulary subtests of the WISC (Wechsler, 1949).

2.6.2 Subjects

The current study compared the performance of a group of 18 dyslexic females to that of a group of 18 non-dyslexic females of equivalent age (mean age of the dyslexics: 9.10, mean age of the non-dyslexics: 10.0, t= -0.089, df= 34, p=0.929).

Participants were volunteers recruited from a private boarding school in the south east. The student body consisted of children from the local area and dyslexics. Although a main stream school, a high percentage of dyslexics attended, as one to one tuition by dyslexia specialists and in-class support was available for dyslexic students. All of the dyslexic subjects had been diagnosed by an Educational Psychologist within five years of the start of the study. The intention was to assess all individuals on the WISC subtests; however, reports indicated that three of the children had been assessed by an Educational Psychologist within the previous nine months. Therefore, to avoid confounding by practice effects, the scores obtained by the Educational Psychologists on WISC-R (Wechsler, 1974) were used. Although this procedure led to three dyslexics undergoing a different testing protocol, analyses indicated no differences between conclusions derived from analyses that incorporated these individuals and conclusions derived from analyses where these individuals were excluded.

The majority of non-dyslexics were from the local area (17 day girls, 1 weekly boarder). The dyslexic sample included more boarders (13 day girls, 4 weekly boarders and 1 full boarder) as children from a wider area attended the school for the dyslexia input. All subjects spoke English as their first language.

2.6.3 Procedure

Subjects were tested individually in a quiet room. The order of test presentation followed that detailed on the WISC record form. Subjects completed the information, arithmetic, vocabulary, digit span and coding subtests from the WISC (Wechsler, 1949). The raw scores produced on these tests were converted using the test manual, into age appropriate scaled scores with a mean of 10 and a standard deviation of 3.

Information: The information subtest assessed memory of purposely learned, factual material. Subjects were required to answer general knowledge questions (e.g. "from what animal do we get milk" or "who was Genghis Khan"). Responses were scored either zero or one based on the marking criteria reported in the test manual. The

maximum raw score was 30. The test was discontinued following five consecutive scores of zero.

Arithmetic: The arithmetic subtest required subjects to mentally calculate verbally presented mathematical problems. Time constraints (ranging from 30 to 120 seconds) were imposed and responses scored either one or zero. The maximum raw score was 16. The test was discontinued following three consecutive scores of zero.

Vocabulary: The vocabulary subtest assessed the individual's word knowledge. It required subjects to define words by providing synonyms, major uses, primary features or general classifications. Responses were scored either zero, one or two based on the marking criteria reported in the test manual. The maximum raw score on the 40 test items was 80. The test was discontinued following five consecutive scores of zero.

Digit Span (Digits Forwards & Digits Backwards): Digit span assessed the recall of phonological information, attention and knowledge/use of rehearsal strategies. It required subjects to repeat an arbitrary series of discrete numbers (presented verbally by the tester) either in the order presented or in reverse. Two trials were administered for each item, and the test was discontinued following failure on both trials. The subject's raw score (out of a maximum of 17) was the sum of total digits forwards and total digits reversed.

Coding: The coding subtest assessed the individual's ability to process information at speed. It required participants to establish associations between symbols and digits on the basis of a provided code. The number of associations (out of a maximum of 93), processed within 120 seconds, represented the subject's raw score.

2.6.4 Results

The performance of dyslexic and non-dyslexic females and comparisons between them is shown in Table 2.14. A graphical comparison displaying test norms (i.e. mean of 10 and a standard deviation of 3) can be found in Graph 2.2.

Table 2.14: Average scaled scores (with standard deviation in brackets) and statistical comparisons (independent sample t-tests) for dyslexic and non-dyslexic females on information, arithmetic, vocabulary, digit span and coding subtests.

	Mean Scaled Score		t-test (df=34)
	Dyslexic Females (N=18)	**Non-dyslexic Females (N=18)**	
Information	9.56 (3.17)	11.94 (2.34)	-2.575 (p=0.015)
Arithmetic	9.11 (3.07)	10.67 (2.28)	-1.729 (p=0.093)
Vocabulary	11.56 (2.96)	12.06 (2.10)	-0.585 (p=0.562)
Digit Span	10.22 (2.51)	10.11 (2.78)	0.126 (p=0.111)
Coding	13.28 (2.89)	13.39 (2.87)	-0.116 (p=0.909)

Graph 2.2: Mean subtest scaled scores for dyslexic and non-dyslexic females on the information, arithmetic, vocabulary, digit span and coding subtests. Average range (7 to 13) is shaded in grey.
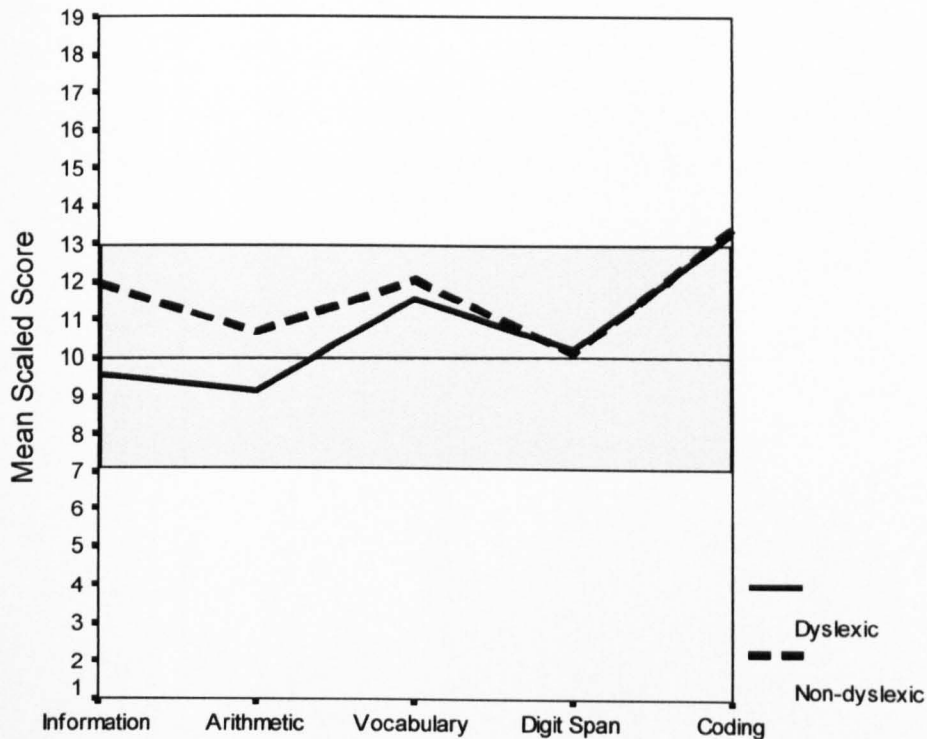
Independent samples t-tests indicated that the non-dyslexics significantly outperformed the dyslexics on the information subtest only. Although the arithmetic subtest approached significance in the predicted direction (i.e., dyslexics worse than non-dyslexics), the scores for digit span and coding were virtually identical across the two groups, and performance on vocabulary varied by less than a quarter of a standard deviation. Identical conclusions were derived from equivalent analyses that excluded the three dyslexic subjects whose scores were taken from their Educational Psychologists reports. These results present very little evidence for ACID/AVID profiles distinguishing between dyslexic and non-dyslexic females.

It is interesting to note that on no subtest did the subject's scaled scores fall below the average range. Both dyslexic and non-dyslexic females showed average performance on digit span and arithmetic, high average performance on vocabulary

107

and above average scores on coding. The weakest score for the non-dyslexics was digit span, whilst for the dyslexics it was arithmetic.

Unlike the data obtained from male samples (see Table 2.13 specifically Neville, 1961; Belmont and Birch, 1966; Thomson and Grant, 1979) which indicated that non-dyslexic males significantly outperform dyslexic males on three or more of the ACID or AVID tests, the performance of the dyslexic and non-dyslexic females only differed significantly on one of the ACID/AVID measures.

2.7 STUDY IVa: Comparison of Dyslexic Males and Females on WISC-III [UK]

The data in section 2.6 suggests that female dyslexics may not be identified by profiling procedures based on the ACID or AVID subtests, such procedures may only be applicable to males. The study reported in Section 2.7 assessed this possibility by specifically contrasting the performance of male and female dyslexics on WISC-III [UK] subtests scores.

2.7.1 Subjects

The private assessments conducted by an Educational Psychologist operating in the South East of England from November 2000 to July 2001 were reviewed. Out of a total of 273 assessments (154 males and 119 females, a ratio of approximately 1.3 to 1) reports for 110 that used WISC-III[UK] (Wechsler, 1992) were selected. Reports were discarded on the basis of the following criteria:

- Individuals who had not been given the WISC. This included individuals over the age of 16.11 to whom the WAIS had been administered (74) and very young subjects who completed the McCarthy Scales of Children's Abilities (6).

- Individuals who had been seen for the purpose of an upgrade assessment and whose report did not contain all of the WISC subtests scores required for the present analysis (25).

- Individuals who were not found to be dyslexic. This included individuals with no apparent difficulties (24) and those with general learning or language difficulties (6). When the latter occurred with dyslexia, it was noted as was the occurrence of dyspraxia and ADHD.

- Individuals for whom English was not their first language (6).

- Individuals of vastly different cultural origins / deprived backgrounds (2).

- In the case of 5 individuals the data files could not be accessed.

- 15 subjects (7 males and 8 females) were excluded as their reports did not included centile scores for the spoonerisms subtest of the Phonological Assessment Battery that was used in analyses reported in section 2.8.

109

Of the 110 subjects who met the criteria, 70 were male and 40 were female (a ratio of approximately 1.75 to 1). The mean age of the whole sample was 10.6 years with a range of 6.3 to 16.8. Within the sample analysed 35 (21 males and 14 females) individuals were recorded as showing 'dyspraxic features', two males showed signs of ADHD and one male exhibited specific language difficulties. All of these characteristics were presented in addition to those associated with dyslexia.

2.7.2 Results

In order to assess potential sex differences, males and females were compared on intelligence quotients, index scores (factor scores that divide WISC-III; see Table 2.15) and individual subtest scaled scores (see Table 2.16), using independent samples t-tests.

Table 2.15: Mean scores (with standard deviation in brackets) and statistical comparisons (independent sample t-tests) for male and female dyslexics. Age, intelligence quotients and index scores are displayed. With the exception of age, measures are presented as standard scores based on a mean of 100 and a standard deviation of 15.

	Dyslexic Males (N=70)	Dyslexic Females (N=40)	t-test (df=108)
Age in months	126.06 (32.63)	130.45 (29.82)	-0.700 (p= 0.485)
Full Scale IQ	107.03 (15.13)	111.33 (18.61)	-1.316 (p= 0.191)
Verbal IQ	113.20 (15.23)	116.58 (13.19)	-1.172 (p=0.244)
Performance IQ	97.43 (15.45)	99.73 (18.46)	-0.698 (p=0.487)
Verbal Comprehension	113.53 (14.53)	117.43 (12.44)	-1.423 (p=0.157)
Perceptual Organisation	99.11 (14.57)	97.40 (17.75)	0.548 (p=0.585)
Freedom from Distractibility	97.46 (14.61)	101.68 (15.43)	-1.427 (p=0.156)
Processing Speed	98.71 (15.33)	110.15 (16.15)	-3.691 (p<0.001)

Table 2.16: Average scores (with standard deviation in brackets) and statistical comparisons (independent sample t-tests) for male and female dyslexics on each subtest of the WICS-III^{UK}. Scaled scores based on a mean of 10 and a standard deviation of 3, are displayed.

	Dyslexic Males (N=70)	Dyslexic Females (N=40)	t-test (df=108)
Information	11.86 (3.52)	12.90 (2.96)	-1.580 (p=0.117)
Similarities	12.41 (2.78)	13.28 (2.23)	-1.674 (p=0.097)
Arithmetic	11.33 (3.45)	11.33 (3.58)	0.005 (p=0.996)
Vocabulary	12.40 (2.78)	12.75 (2.44)	-0.664 (p=0.508)
Comprehension	12.97 (2.85)	13.50 (2.61)	-0.964 (p=0.337)
Digit Span	7.80 (2.56)	9.33 (2.81)	-2.900 (p=0.005)
Picture Completion	10.71 (2.53)	10.45 (2.72)	0.513 (p=0.609)
Picture Arrangement	9.93 (3.81)	9.20 (3.74)	0.971 (p=0.334)
Block Design	10.16 (3.26)	9.80 (3.16)	0.560 (p=0.577)
Object Assembly	8.79 (2.83)	9.15 (3.60)	-0.587 (p=0.558)
Coding*	8.97 (2.89)	11.15 (3.48)	-3.352 (p=0.001)
Symbol Search	10.54 (3.10)	12.53 (2.97)	-3.278 (p=0.001)

* For coding, equal variance not assumed in the analysis.

112

Contrary to the findings reviewed by Vogel and Walsh (1987), the female dyslexics outperformed the male dyslexics on all three intelligence quotients, although these differences were not significant. The females also outperformed males on the verbal comprehension, freedom from distractibility and processing speed index scores. However, the difference was only statistically significant for the index of processing speed. Although males achieved a slightly higher score than females on the index of perceptual organisation, this difference was non-significant.

On the majority of individual subtests, no differences were identified between the sexes. Males were superior to females on picture completion, picture arrangement and block design. However, these differences were minimal and non-significant. The performance of the females on information, similarities, vocabulary, comprehension and object assembly was marginally superior to that of the males, but again these differences were not significant. Statistically significant differences were identified on the digit span, coding and symbol search subtests, on which the females outperformed the males.

Both groups showed a significant discrepancy between verbal and performance IQ (approximately 16 points in both cases). For both males and females, verbal IQ was considerably greater than performance IQ. The mean verbal IQ for the entire sample of dyslexics was 114.43 which was over a standard deviation higher than the mean performance IQ of 98.26. This is not a typical finding amongst dyslexic samples. For example, Thomson and Grant (1979) reviewed the findings of Graham (1956), Schiffman and Clemmens (1966) and Neville (1961) who identified relatively higher performance IQs (as opposed to verbal IQs) within groups of retarded readers. In addition, comparisons with 'normal' readers indicated that the frequency of this relationship (performance > verbal) was greater in samples of retarded readers (Naidoo, 1972; Rutter, Tizard and Whitmore, 1971). Discrepancies in favour of performance IQ have also been identified in college students (Vogel and Walsh, 1987) and adults (Alm and Kaufman, 2002) with dyslexia.

Within their own sample of dyslexics, Thomson and Grant (1979) identified the opposite pattern (verbal > performance), although the difference was minimal

(approximately two thirds of a standard deviation). Altus (1956), Kallos (1961), Robeck (1960) and Spafford (1989) found only 'negligible' differences between verbal and performance IQs, that Kallos (1961) described as not "diagnostically significant" (page 477). In light of such inconsistencies, Thomson and Grant (1979) concluded that "a superior performance IQ may be associated with dyslexic problems, but that this distinction is by no means conclusive and would not merit diagnostic use in the individual case" (page112).

Vogel (1986) and Kaufman (1990) both argued that higher verbal IQ than performance IQ may be linked to advanced educational levels, with lower levels being associated with the opposite profile of performance greater than verbal. When Alm and Kaufman (2002) examined the relationship between verbal and performance IQ within the different 'educational groups' in their sample of dyslexics, they found that the discrepancy decreased from 12.1 points in the group with the fewest years of education to a non-significant 3.2 points in the group with the greatest number of years in education. However, even within the latter group, performance IQ was still in advance of verbal IQ. Such findings suggest that education has a positive and quite specific effect on verbal abilities. This is not surprising when considering those tests that constitute the verbal scale. As previously mentioned, the information and arithmetic subtests assess knowledge predominantly acquired at school. Similarly, the word knowledge and verbal reasoning skills required for vocabulary and similarities are likely to be enhanced by education. If dyslexics do not benefit from education in the same way as non-dyslexics, one might expect a continued performance greater than verbal profile. Given that the dyslexics in the present study show a verbal greater than performance profile, it may be argued than they benefit from education in a similar way to non-dyslexics. However, an alternative interpretation is that the differences reported in the literature represent a marginal or inconsistent difference between these global IQ scores and that such indexes may not be appropriate for diagnostic purposes.

Figure 2.1: Hierarchy of mean index scores for male and female dyslexics.

```
INDEX SCORES

Males                          Females
Verbal Comprehension           Verbal Comprehension
Perceptual Organisation        Processing Speed
Processing Speed               Freedom from Distractibility
Freedom from Distractibility   Perceptual Organisation
```

Figure 2.2: Hierarchy of mean subtests scaled scores for male and female dyslexics.

```
INDIVIDUAL SUBTESTS

Males                  Females
Comprehension          Comprehension
Similarities           Similarities
Vocabulary             Information
Information            Vocabulary
Arithmetic             Symbol Search
Picture Completion     Arithmetic
Symbol Search          Coding
Block Design           Picture Completion
Picture Arrangement    Block Design
Coding                 Digit Span
Object Assembly        Picture Arrangement
Digit Span             Object Assembly
```

Graph 2.3: Mean subtest scaled scores for male and female dyslexics. Average range (7 to 13) is shaded in grey.
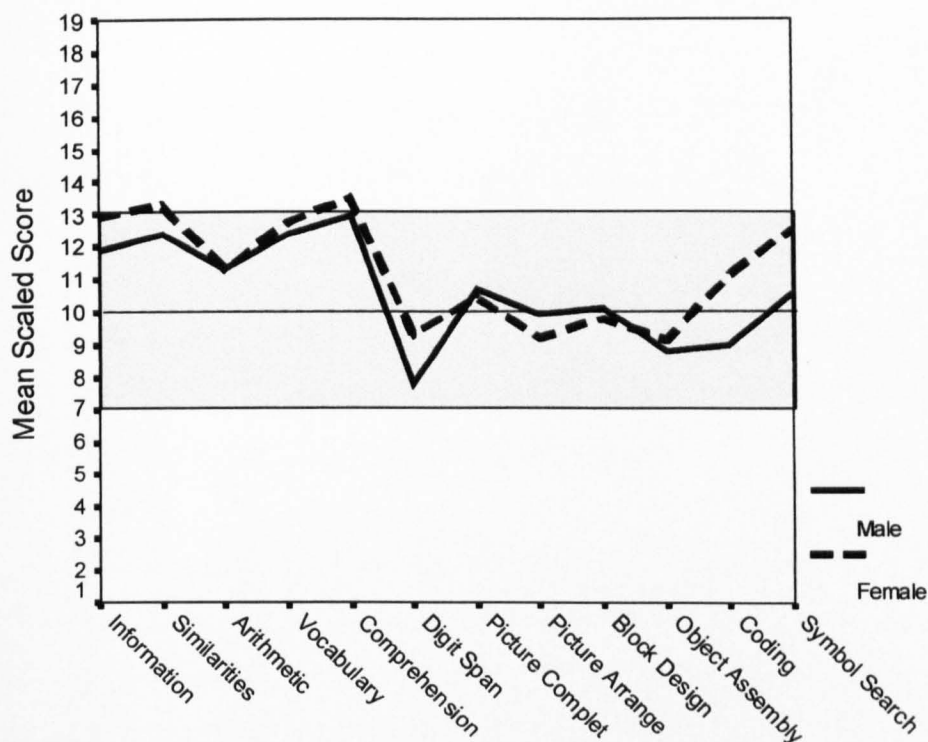
When the mean index scores are represented as a hierarchy (see figure 2.1) the performance of the females is similar to that predicted by the sex differences literature. Verbal comprehension represented their highest index score whilst their lowest score was obtained on the index of perceptual organisation. The pattern displayed by the males is not so consistent with that predicted. For example, instead of demonstrating relative non-verbal strengths, the highest index score obtained by the males was also verbal comprehension. This was followed by perceptual organisation, processing speed and freedom from distractibility. Consistent with the findings of Vogel & Walsh (1987), dyslexic males achieved their lowest scores on the factors that contain three out of the four ACID tests.

When the individual subtest scores were represented as a hierarchy (see figure 2.2), the highest score obtained by both males and females was on the comprehension subtest. The lowest score obtained by females was on object assembly, whilst digit span represented the lowest score for males. Information and vocabulary were within

116

the top five tests for both males and females. Arithmetic and symbol search occupied a similar central position for both groups, whilst coding represented a relative strength for females and a relative weakness for males. Both groups showed relatively poor performance on digit span, especially the males.

The identification of relative strengths on information and arithmetic is inconsistent with previous findings. For example, Vogel & Walsh (1987) refer to the findings of Ryckman (1981), Tittemore, Lawson and Inglis (1985), Eno and Woehlke (1980) and Vance, Singer and Engin (1980) all of whom reported that information was more often in the lower half of the hierarchy, a finding that was not replicated by the current study. Both males and females showed good scores on information with regard to test norms and in relation to performance on the other tests.

For studies with predominantly male samples poor performance on arithmetic was identified more consistently than deficits on any of the other ACID tests (see Table 2.13). Within the current study both dyslexic males and females produced average scores on arithmetic and the position of arithmetic within the subtest hierarchy did not portray it as a relative weakness for either group.

The extent to which the ACID subtests appeared within the bottom four subtest scores was also examined for each subject individually. The procedure described in the WISC-III^{UK} manual for identifying an ACID profile was adopted. E.g. "the full ACID profile was defined as occurring when the scaled scores on all four of the ACID subtests are equal to or less than the lowest scaled score on any of the remaining subtests" (Wechsler, 1992, page 103). According to this criteria only 2 of the 70 dyslexic males (2.8%) showed a full ACID profile, whilst 10 (14.3%) showed partial ACID profiles (e.g. three out of the four ACID tests appeared within the bottom four subtest scores). No dyslexic females showed the full ACID profile and only 2 out of the 40 females (5%) showed a partial profile.

The frequency with which a full ACID profile was identified within the current sample of dyslexic males is reasonably consistent with previous findings. For example, Prifitera and Dersch (1993) identified the full ACID profile in 5.1% of their

sample of children with specific learning difficulties. Watkins et al (1997) reports a frequency of 4.1% and Ward et al (1995) a frequency of 4.7%. According to Ward et al (1995) "the low incidence of the profile in the clinical samples renders it clinically meaningless. Therefore, the ACID profile should not be required for diagnosis, nor should the mere absence of the ACID profile be sufficient evidence to relinquish suspicion of a disability" (page 274).

A similar procedure to that used to identify the ACID profile was adopted to identify AVID and SCAD profiles. This was done to ensure consistency; however, it should be noted that the existence of the SCAD profile can also be determined by comparing the sum of the four scaled scores that comprise SCAD, to the sum of the four scaled scores that comprise the index of perceptual organisation (Kaufman, 1994). One dyslexic male (1.4%) and no dyslexic females showed full AVID profiles, whilst 7 males (10%) and 3 females (7.5%) showed partial AVID profiles. Two dyslexic males (2.9%) and 1 dyslexic female (2.5%) showed full SCAD profiles and 26 males (37.1%) and 5 females (12.5%) showed partial SCAD profiles.

The extent to which each subtest represents a significant strength or weakness was also examined. For each dyslexic it is also possible to determine whether there is a 'meaningful' difference (i.e. a statistically significant difference, the frequency of which is uncommon among normal children) between individual subtest scores and the mean of the remaining subtests. Table 2.17 shows the percentage of males and females for whom a particular subtest represented a significant strength or weakness at a level that would not be expected in 85% of people. For example, digit span represented a significant weakness for 68% of dyslexic males and a significant strength for 1% of dyslexic males.

Table 2.17: Percentage of males and females for whom a given subtest represented a significant strength (S) or weakness (W).

	% of males and females that showed a significant strength or weakness on each subtest			
	Dyslexic Males (N=70)		Dyslexic Females (N=40)	
	W	S	W	S
Digit Span	68%	1%	47%	3%
Coding	16%	1%	5%	21%
Object Assembly	16%	1%	21%	3%
Picture Arrangement	16%	13%	18%	3%
Arithmetic	13%	6%	29%	3%
Information	11%	11%	8%	11%
Symbol Search	7%	20%	0%	37%
Block Design	6%	3%	11%	5%
Picture Completion	4%	13%	0%	5%
Vocabulary	1%	9%	3%	5%
Comprehension	1%	9%	3%	11%
Similarities	1%	6%	0%	8%

For males the results displayed in Table 2.17 are consistent with the hierarchy of scores shown in Figure 2.2. For example, dyslexic males obtained their lowest score on digit span which also presented as a significant weakness for the majority of males. Results pertaining to object assembly, coding and picture arrangement were also consistent across the different analyses.

For the females results were slightly less consistent. Although object assembly and picture arrangement were lower than digit span in the hierarchy of mean subtest scaled scores, dyslexic females were more likely to show significant weaknesses on digit span. Arithmetic also represented a significant weakness more frequently than would have been expected from the hierarchy of mean subtest scaled scores.

Information, vocabulary, and symbol search did not appear to represent areas of weakness for either dyslexic males or females (symbol search, in particular, being more likely to represent a significant strength for both groups). Digit span presented as a relative weakness for the majority of males and for approximately half of the females, whilst coding, a relative weakness for males was more likely to be a relative strength for females. Males therefore, performed relatively poorly on two ACID and two SCAD subtests (coding and digit span in both cases) and on one AVID subtest (digit span), whilst females demonstrated a slight weakness on only one of the four tests within these profiles (e.g. digit span).

Overall, these findings suggest that full ACID, AVID or SCAD profiles do not characterise the performance of either dyslexic males or females and therefore do not represent a reliable means of identifying dyslexia.

2.7.3 Modifications and Future Research

One weakness of the research presented this section was the reliance on comparisons with test norms. Although unlikely, there could have been a specific tester-testee interaction that lead to performance on the ACID, AVID and SCAD factors that differed from that normally found with WISC-based assessments. The same assessor testing dyslexic and non-dyslexic individuals would help to clarify, for example, whether non-dyslexic males outperform dyslexic males on these WISC factors. The inclusion of a group of non-dyslexics would also have facilitated profile comparisons, i.e. would non-dyslexics have shown similar weaknesses on object assembly, picture arrangement and block design. On the basis of the sex differences literature, females might be expected to show relative weaknesses on these and other performance sub-tests. If non-dyslexic females showed a similar profile, the performance of the dyslexic females could possibly be attributed to their sex (e.g. they were behaving like 'normal' females). However, the present data are surprising in that the dyslexic males also performed relatively poorly on these measures; a pattern of performance which would not be predicted on the basis of their sex. If male and female non-dyslexics did not score poorly on these measures, the possibility exists that deficits on these tasks may be related to dyslexia. Alternatively,

120

if all groups (dyslexic, non-dyslexic, males and females) showed a similar profile it may be that some form of assessment effect was in operation (e.g. there was something about the way this specific sample was tested that resulted in this anomalous finding). Since this section involved the analysis of secondary data it is not possible to eliminate this possibility.

2.8 STUDY IVb: The Relationship Between WISC-III^{UK} Profiles and Various Measures of Literacy Attainment

2.8.1 Procedure

Although the performance of the dyslexics analysed in section 2.7 was not characterised by the ACID, AVID and SCAD profiles, it may be that the severity of their difficulties can be predicted by these indexes and that more severe learning difficulties may be identified through these WISC related procures. In order to assess this possibility the current analysis sort to determine the extent to which the ACID, AVID and SCAD factors, and the individual subtests of which these are comprised, predict the reading, spelling and phonological processing ability of the dyslexics analysed in section 2.7.

For each of the subjects in section 2.7, the mean of the scaled scores for arithmetic, coding, information and digit span were calculated to produce an ACID factor score. Similarly, the mean of arithmetic, vocabulary, information and digit span was determined to produce an AVID factor score. The more recent SCAD factor was derived from the mean of symbol search, coding, arithmetic and digit span. The performance of dyslexic males and females on the ACID, AVID and SCAD factors was contrasted, as were centile scores derived from The British Ability Scales (BAS) word reading test, the Helen Arkell spelling test and the spoonerisms subtest from the Phonological Assessment Battery (PhAB). These scores were also taken from the Educational Psychological reports from which the WISC-III^{UK} data was derived.

British Ability Scales (BAS) Word Reading Test (Elliott, 1996): Subjects were required to read 90 words of increasing complexity. The test was discontinued after 10 incorrect responses and/or omissions. The number of words pronounced correctly represented the subject's single word recognition score out of a maximum of 90. Raw scores were converted into age appropriate centile scores.

Helen Arkell Spelling Test (Brooks, and McLean, 1998): Subjects were required to spell 140 words of increasing complexity. The test was discontinued after 10 incorrect responses and/or omissions. The number of words spelt correctly

122

represented the subject's spelling score out of a maximum of 140. Raw scores were converted into age appropriate centile scores.

PhAB Spoonerisms (Frederickson, Frith and Reason, 1996): The spoonerisms test consisted of a semi-spoonerisms subtest and a full spoonerism subtest. The semi-spoonerisms subtest required subjects to replace the first sound of a word with a given sound ('fun' with a 'b' = 'bun'). The full spoonerisms subtest involved the transposition of initial sounds from two words ('fed' and 'man' = 'med fan'). The full spoonerisms subtest was only administered to children over the age of 7 who managed to score on semi-spoonerisms. Each subtest was discontinued following three consecutive incorrect responses or when the three minute time limit had expired. Phonological processing was measured as the number of correct responses out of a maximum of 30. Raw scores were converted to age appropriate centile scores.

2.8.2 Results

Table 2.18: Scores for dyslexic males and females on the ACID, AVID and SCAD Factors. Centile scores for the BAS word reading test, the Helen Arkell spelling test and PhAB Spoonerism are also shown. Average scores (with standard deviation in brackets) and statistical comparisons (independent sample t-tests) are displayed.

	Dyslexic Males (N=70)	Dyslexic Females (N=40)	t-test (df=108)
ACID Factor	9.99 (2.22)	11.18 (2.07)	-2.763 (p=0.007)
AVID Factor	10.85 (2.38)	11.58 (2.19)	-1.588 (p=0.115)
SCAD Factor	9.66 (2.29	11.08 (1.86)	-3.342 (p=0.001)
BAS II Word Reading Test* (Centile)	52.70 (30.39)	67.25 (25.51)	-2.680 (p=0.009)
Helen Arkell Spelling Test* (Centile)	44.53 (30.73)	57.45 (26.21)	-2.333 (p=0.022)
PhAB Spoonerisms (Centile)	41.69 (24.54)	52.03 (23.16)	-2.169 (p=0.032

*For reading and spelling, equal variance was not assumed in the analyses.

The dyslexic females achieved higher ACID, AVID and SCAD factor scores than the dyslexic males. However, independent samples t-tests indicated that these differences were only significant for the ACID and SCAD factors. For both groups, all three factor scores were within the average range. Independent samples t-tests also indicated that the female dyslexics significantly outperformed the dyslexic males on the reading, spelling and phonological processing tasks. However, the performance of both groups did not appear particularly weak with no scores falling below the 40th percentile.

Pearson Product Moment correlations were performed in order to identify any relationships between reading, spelling and spoonerisms and the ACID, AVID and SCAD factors. Males and females were analysed separately. Correlations are shown in Tables 2.19 and 2.20.

Table 2.19: Correlations between reading, spelling and spoonerisms and the ACID, AVID and SCAD factors for dyslexic males.

	Dyslexic Males (N=70)		
	ACID	AVID	SCAD
BAS II Word Reading Test (Centile)	0.600**	0.686**	0.450**
Helen Arkell Spelling Test (Centile)	0.512**	0.603**	0.384**
PhAB Spoonerisms (Centile)	0.504**	0.556**	0.430**

** Correlation significant at the 0.01 level

* Correlation significant at the 0.05 level

Table 2.20: Correlations between reading, spelling and spoonerisms and the ACID, AVID and SCAD factors for dyslexic females.

	Dyslexic Females (N=40)		
	ACID	AVID	SCAD
BAS II Word Reading Test (Centile)	0.580**	0.637**	0.366*
Helen Arkell Spelling Test (Centile)	0.676**	0.693**	0.540**
PhAB Spoonerisms (Centile)	0.241	0.353*	0.125

** Correlation significant at the 0.01 level

* Correlation significant at the 0.05 level

For the male dyslexics, highly significant positive correlations were identified between the ACID, AVID and SCAD factors and reading, spelling and phonological processing. As ACID, AVID and SCAD factor scores increased so did reading, spelling and phonological processing ability. Similar results were obtained for dyslexic females, with the ACID, AVID and SCAD factors proving to be highly correlated with reading and spelling ability. However, for the females, the size of the relationships between phonological processing and the three factor scores was much smaller than might be expected based on the findings with males (the correlation between phonological processing and the ACID and SCAD factors failing to reach significance).

Pearson Product Moment correlations were also performed in order to identify any relationship between reading, spelling and spoonerisms and the individual subtests of arithmetic, coding, information, digit span, vocabulary and symbol search. The relationship between phonological awareness and reading and spelling was also investigated. Males and females were again analysed separately. These correlations are shown in Tables 2.21, 2.22 and 2.23.

Table 2.21: Correlations between BAS Word Reading Test and arithmetic, coding, information, digit span, vocabulary, symbol search and spoonerisms for male and female dyslexics.

	BAS II Word Reading Test (Centile)	
	Dyslexic Males (N=70)	Dyslexic Females (N=40)
Arithmetic	0.583**	0.450**
Coding	0.096	0.046
Information	0.570**	0.625**
Digit Span	0.398**	0.422**
Vocabulary	0.583**	0.383*
Symbol Search	0.267*	-0.077
Spoonerisms	0.530**	0.347*

** Correlation significant at the 0.01 level

* Correlation significant at the 0.05 level

The reading ability of the dyslexics males was found to be positively correlated with all measures accept coding. For females, reading ability was correlated with all measures accept coding and symbol search. In order to determine which of the predictor variables (arithmetic, coding, information, digit span, vocabulary, symbol search or spoonerisms) accounted for the most variance in word reading, a regression analysis was carried out using the Stepwise Method. For dyslexic males, the single best predictor of reading ability was arithmetic, which accounted for approximately 34% of the variance in reading ability (R^2=0.340, p<0.001). The addition of spoonerisms increased the amount of variance predicted by approximately 9% (R^2=0.430, p<0.001). Information predicted an additional 5% (R^2=0.484, p<0.001). For dyslexic females, information was the single best predictor of reading ability, accounting for approximately 39% of the variance (R^2=0.391, p<0.001).

Table 2.22: Correlations between performance on the Helen Arkell Spelling Test and arithmetic, coding, information, digit span, vocabulary, symbol search and spoonerisms for male and female dyslexics.

	Helen Arkell Spelling Test (Centile)	
	Dyslexic Males (N=70)	Dyslexic Females (N=40)
Arithmetic	0.476**	0.514**
Coding	0.064	0.213
Information	0.480**	0.608**
Digit Span	0.399**	0.435**
Vocabulary	0.502**	0.496**
Symbol Search	0.215	0.074
Spoonerisms	0.553**	0.383*

** Correlation significant at the 0.01 level

* Correlation significant at the 0.05 level

The spelling ability of both dyslexic males and females was found to be positively correlated with all measures accept coding and symbol search. Stepwise regression analyses were carried out in order to determine which of the predictor variables (arithmetic, coding, information, digit span, vocabulary, symbol search and spoonerisms) accounted for the most variance in spelling ability. For dyslexic males, the single best predictor of spelling ability was spoonerisms which accounted for approximately 31% of the variance (R^2=0.305, p<0.001). The addition of vocabulary increased the amount of variance predicted by approximately 8% (R^2=0.386, p<0.001). Information was determined to be the single best predictor of spelling ability for dyslexic females, accounting for approximately 37% of the variance (R^2=0.369, p<0.001). The addition of arithmetic increased the amount of variance predicted by approximately 7% (R^2=0.436, p<0.001).

Table 2.23: Correlations between performance on PhAB Spoonerisms and arithmetic, coding, information, digit span, vocabulary and symbol search for male and female dyslexics.

	PhAB Spoonerisms (Centile)	
	Dyslexic Males (N=70)	**Dyslexic Females (N=40)**
Arithmetic	0.449**	0.205
Coding	0.145	0.056
Information	0.430**	0.394*
Digit Span	0.385**	-0.032
Vocabulary	0.450**	0.528**
Symbol Search	0.318**	0.033

** Correlation significant at the 0.01 level

* Correlation significant at the 0.05 level

Table 2.23 shows a different relationship between phonological processing ability and the ACID, AVID and SCAD subtest scores for dyslexic males and females. For males, phonological processing appears to be highly correlated with all the subtests accept coding. For females, the ability to manipulate phonological information appears to share variability predominantly with vocabulary and to a lesser extent with information. Stepwise regression analyses were carried out in order to determine which of the predictor variables (arithmetic, coding, information, digit span, vocabulary or symbol search) accounted for the most variance in phonological processing. For dyslexic males, vocabulary was found to be the single best predictor of phonological processing, accounting for approximately 20% of the variance (R^2=0.202, p<0.001). The addition of arithmetic increased the amount of variance predicted by approximately 5% (R^2=0.251, p<0.001). Vocabulary was also determined to be the single best predictor of phonological processing ability for

dyslexic females, accounting for approximately 28% of the variance (R^2=0.279, p<0.001).

Although not particularly representative of the performance of either group, these findings suggest that the ACID, AVID and SCAD factor scores are more related to dyslexia in males than females. For example, these factor scores appeared more related to the phonological processing ability of dyslexic males than dyslexic females. As ACID, AVID and SCAD factor scores increased so did performance on the phonological processing task. These factor scores could therefore provide an indication of the severity of the phonological processing deficits experienced by dyslexic males. These findings also suggest that phonological processing ability is more related to literacy skills in dyslexic males, with the reading and spelling ability of dyslexic females being predicted by more environmental factors (e.g. exposure to print and educational opportunity).

2.8.3 Modifications and Future Research

Different skills appeared to predict the reading and spelling ability of the 10 year old dyslexic males and females. Longitudinal research could examine the predictors of literacy skills at different ages (younger and older) to determine whether these relationships remain stable over time. For example, it may be age or level of literacy development that determines the relative importance of phonological processing on reading and spelling ability. The current findings could reflect developmental differences between males and females. If the literacy development of males is considered delayed relative to that of females, similar relationships to that seen in dyslexic female children might be observed in older males (i.e. with age the reading and spelling ability of dyslexic males may also become less reliant on phonological processing). As differences between the sexes decrease with age, or as males 'catch up', the predictors of literacy skills may present as more consistent across the sexes. Alternatively, the literacy skills of dyslexic males and females could be predicted by different variables that follow different developmental sequences specific to each sex.

130

The previous section showed that dyslexic females significantly outperformed dyslexic males on both reading and spelling tasks. Furthermore, variance in the reading and spelling ability of males and females was predicted by different variables. The final section of Chapter 2 examines the extent to which males and females benefit from different methods of spelling instruction, i.e. whether innate cognitive sex differences predispose to differential learning styles.

2.9 STUDY V: Sex Differences and Remediation.

2.9.1 Introduction

The current study investigated whether cognitive sex differences predisposed to differential learning styles. For example, the extent to which females utilised their verbal advantage and males their visuospatial advantage during literacy acquisition. Research concerning reading development has suggested that males and females rely on different linguistic strategies. For example, Liberman and Mann (1981) maintained that females advanced to more sophisticated phonological decoding strategies prior to males. Similarly, Bakker and Moerland (1981) hypothesised that differences in reading development resulted from the persistent use of right hemisphere, visuospatial approaches to reading in males (Bryden, 1981) and the untimely use of left hemisphere linguistic reading strategies in females. Kandel and Tsao (1981) extended these hypotheses by suggesting the methods of instruction best suited to the different sexes. They maintained that the whole word method of reading instruction was more compatible with the cognitive style of most boys, whilst girls procured greater advances in reading via phonics instruction. Such research points to a female learning style that is more congruous with linguistic or phonic approaches to instruction and a male learning style that is more reliant on visual strategies. The study reported in this section of the thesis investigates the relationship between dyslexia, gender and various methods of literacy instruction, in order to determine how the cognitive strengths and weaknesses that define dyslexia interact with cognitive sex differences to affect response to spelling instruction.

Spelling is an extremely complex task involving the retrieval and production of an exact sequence of letters. Successful spelling requires precise and complete knowledge of a word's orthography and is consequently considered more demanding than reading, which is essentially a recognition task. Phonology is also believed to play a greater role in spelling than reading, with alphabetic skills initially developing to support spelling acquisition. Phonological deficits 'should' therefore have a greater impact on spelling than reading (Treiman, 1977). Spelling represents one of the most severe, persistent and difficult to remediate deficits associated with

132

dyslexia. Despite this, it has received less attention than reading with regard to research and instruction in schools (Fulk & Stormont-Spurgin, 1995).

Dyslexics find it difficult to incidentally learn new spellings whilst reading. They require externally directed, systematic study techniques. Traditional methods of spelling instruction have, in general, proven unsuccessful with dyslexics. The self-study of fifteen to twenty weekly spellings frequently assigned by class teachers is an overwhelming task for the dyslexic and typically fails to procure long term gains or the generalisation of learnt vocabulary (Graham and Voth, 1990). All children benefit from instruction in the use of spelling strategies (Butyniec-Thomas and Woloshyn, 1997). However, Kearney and Drabman (1993) and McNaughton, Hughs and Clark (1994) highlighted the importance of this with regard to dyslexics, maintaining that dyslexic students lack, or do not instinctively use, strategies for retaining novel spellings. The use of explicit spelling instruction has been found to improve the spelling ability of dyslexic students relative to unstructured study. Spelling intervention studies (for a review see Fulk & Stormont-Spurgin, 1995; Gordon, Vaughn and Schumm, 1993) suggest that the following techniques either combined or in isolation considerably enhance the effectiveness of spelling programmes:

- Error imitation and modelling
- Positive reinforcement/reward
- Reduced unit size
- Immediate feedback
- Distributed practice

However, since most of the studies which reported success with these techniques were either single case studies, or their design did not include a control group, it remains unclear whether any of these techniques were specifically beneficial to dyslexics, incurring spelling improvements in advance of those attributable to increased adult attention, motivation or the application of structure in general.

Graham and Voth (1990) describe a procedure whereby weekly spelling lists consisting of six to twelve related words are introduced daily, in groups of no more than two or three. The list should consist of either words misspelled by the student in their own writing, subject specific vocabulary or words that include the use of a corresponding spelling rule; e.g. 'or' after 'w' says /er/ (work, word, worse, worth, worship & worthless). Short, distributed practice sessions spanning the week should take place as opposed to 'massed practice'. Immediate, self-correction of the daily pre-tests (assessing new and previously introduced words) should occur as part of the instructional session, and subsequent emphasis should be placed on misspelled words. Post testing should occur at the end of each instruction session, providing both student and teacher with an indication of spelling improvement. Revision of misspelled words occurs until the lists are mastered. 'Maintenance checks' are conducted for as long as six months after the initial introduction of the stimulus words, misspelled or forgotten words being reintroduced into the instructional cycle. Once spelling skills are acquired, Graham and Voth (1990) suggest focussing on automaticity. Computer games provide entertaining drill and practice activities that support spelling fluency.

An effective spelling programme should also promote generalisation. This takes two forms, the use of learnt vocabulary in other learning situations (e.g. free writing), something that dyslexics do not do automatically, and the ability to apply the spelling strategy to the learning of novel words. Finally, a spelling programme should encourage self correction, as this facilitates the development of metacognitive strategies and an awareness of one's own performance.

Competent spellers are able to derive the correct spelling of a word via distinct sublexical and lexical spelling processes. The sublexical route utilises phonology to orthography conversion mechanisms. Spoken input (as in a dictated spelling test) is subject to acoustic analysis and segmented into smaller phonological units (e.g. syllables, onset and rime or phonemes) which are then converted into the corresponding orthographic units and sequenced into a letter string. This conversion process is mediated by the grapheme / phoneme correspondence rules that exist in alphabetic writing systems. The selection of a correspondence depends on the

frequency with which it occurs in a given language and the context (e.g. position in the word). This process can only be successfully applied to the spelling of regular words and non-words that obey these correspondence rules. Attempts to spell irregular words via this route often results in phonologically plausible or regularisation errors. The lexical spelling process involves accessing the orthographic representation of known letter strings (e.g. familiar words) from the orthographic lexicon or sight vocabulary. During an oral/dictated spelling test, the complete phonological representation of the target word would be activated in the phonological lexicon. This would excite the associated concept in the semantic system, which in turn activates the orthographic representation of the word in the orthographic lexicon. In this way even irregular words may be spelt correctly.

Lexical and sublexical processes are believed to run in parallel, producing abstract letter representations that combine to activate the correct letter string in the graphemic buffer. The graphemic units remain activated whilst the letter string is transformed into either written or verbal output. The independence of these procedures until the later stages of spelling production means that if one process is functioning inefficiently the other is able to produce a letter representation.

As described in Chapter 1, the typical constellation of dyslexic difficulties is generally perceived as including some form of phonological awareness or phonological processing deficit. If the phonemes represented within the language processing system lack specificity, or the efficiency with which they are utilised during encoding is deficient, sublexical spelling is likely to be compromised. As such, it has been suggested that compensatory reliance on visual memorization and semantic skills is fundamental to the development of spelling skills in dyslexics (Treiman, 1997). Following a review of the literature, Treiman (1997) concluded that dyslexics demonstrated a pervasive tendency to make spelling errors similar to those made by younger non-dyslexics. The reasonable but 'primitive' use of phonology was attributed to the absence of fine grained connections between phonology and orthography. In other words, "dyslexic's errors, to a greater degree than normals', may reflect the use of units larger than single phonemes" (Treiman, 1997, page 212). In contrast, knowledge of orthography was considered appropriate with regard to the

135

individual's general level of literacy development. Research suggests that the dyslexic's ability to spell is supported by their relative visual/orthographic strengths. For example, Martlew (1992) found that dyslexic's non-word spelling errors often took the form of 'real word approximations', suggesting the use of lexical mechanisms.

As well as influencing the inherent spelling strategies available to dyslexics, this pattern of cognitive strengths and weakness will also affect how the individual interacts with different methods of spelling instruction. Graham and Voth (1990) suggested that spelling strategies should capitalise on existing spelling skills and that the efficiency of an instructional technique depends on the presence of sufficient "domain-specific knowledge" (page 415). Similarly, Kearney and Drabman (1993) maintained that it was "imperative to identify and target sensory strengths that may compensate for concurrent sensory weaknesses" (page 55). The effectiveness of an intervention depends on its interaction with the cognitive profile of the individual to whom it is applied (Brooks, 1995). In the case of dyslexics, greater advances would be anticipated following strategies that build upon visual-semantic strengths.

Brooks and Weeks (1999) compared advances in spelling ability made by dyslexic and spelling age matched controls (SA) following either visual-semantic or phonics instruction. Their findings indicated that the dyslexic group made greater advances in spelling following the visual-semantic method of instruction, whilst the control group showed similar levels of improvement across teaching methods. In addition to demonstrating that dyslexics benefit from instructional methods that are tailored to their cognitive strengths, these findings were also consistent with the sex differences literature as 83% of Brooks and Weeks (1999) dyslexic sample were male, and would therefore be expected to benefit from visual teaching strategies.

In summary, the remedial literature maintains that the strengths and weaknesses that define dyslexia determine what cognitive resources the individual can apply to a learning situation. The sex differences literature points to a female learning style that is more congruous with linguistic or phonic approaches to instruction and a male learning style that is more reliant on visual strategies.

On the basis of these predictions the current study investigated the interaction between method of spelling instruction, sex and group (dyslexic verses non-dyslexic). Additional aims focused specifically on the performance of the dyslexics and considered the rate and endurance of spelling improvement, as well as investigating potential predictors of spelling ability.

The current study aimed to investigate:

- The interaction between 'method of instruction', sex and group.
- The interaction between the dyslexic's rate of improvement and sex.
- The interaction between the dyslexic's ability to maintain spelling knowledge and sex.
- Predictors of dyslexics' spelling improvement following intervention.

2.9.2 Subjects

Participants in the investigation were volunteers recruited from a private, primary school in East London. The experiment was run during three consecutive summer terms on selected children from Form 4 (1997-1998, 1998-1999 & 1999-2000).

Fifty-three subjects, 24 dyslexics (12 male, 12 female) and 29 non-dyslexics (10 male, 19 female), with a mean age of 11.2 (134.45 months, standard deviation: 3.59), participated in the investigation. Subjects were divided into two groups (A and B) that were matched for number of dyslexics, sex, age and spelling ability (SATS spelling score). Group statistics are shown in Table 2.24.

Table 2.24: Number of dyslexics, non-dyslexics, males and females included in the two experimental groups. Average age and SATS spelling score (with standard deviation in brackets) and statistical comparisons are also displayed.

	Group A (N=27)	Group B (N=26)	t-test (df=51)
Dyslexics	5 males 7 females	7 males 5 females	-
Non-dyslexics	6 males 9 females	4 males 10 females	-
Age in months	134.89 (3.40)	134.00 (3.78)	t=0.900 (p= 0.372)
SATS Spelling out of 20	11.26 (6.96)	9.92 (7.02)	t=0.693 (p= 0.386)

As can be seen from Table 2.24, the two experimental groups contained similar numbers of dyslexics, males and females, and did not differ significantly in terms of age or SATS spelling score.

2.9.3 Procedure

Each group (A and B) was required to learn two spelling lists (list 1 and 2). Each list contained 15 equivalent words taken from the Dyslexia Institute Structured Spelling Test (Chasty, unpublished), the Schonell Graded Spelling Test – Form A (Schonell, 1970), the Schonell Graded Spelling Test (Schonell, 1976) and the Vernon Graded Word Spelling Test (Vernon, 1977). Words that were used to distinguish 12 year old spellers from 11 year old spellers were selected from each test. No word that distinguished a 13 year old speller from a 12 year old speller was used. From the corpus of words taken from the spelling tests, those which could be paired with equivalent words in the list were chosen. Pairing was based on written frequency, part of speech (e.g. nouns, verbs, adjectives etc) and concreteness using the Oxford Psycholinguistic Database (Wilson, 1988). The words in each list were also matched for number of syllables. No phonologically irregular words were included. Word lists are shown in Appendix A.

The spellings within each list were taught to subjects by either a sound based phonics method or a visual-semantic method of spelling instruction.

Phonics intervention: A magnet board and plastic letters were used to divide words at varying levels of analysis; e.g. syllabic, onset-rhyme and phonemic. At the level of the syllable, emphasis was placed on the number of beats within a particular word. For example, the word 'genuine' has three beats, (gen u ine). The individual phonemes within each syllable were sounded out and any applicable rules discussed (in the case of genuine, 'soft g' and' u' as an open syllable making a long vowel sound). Following these discussions, the letters were 'muddled up' and the subject required to reorganise them into the correct spelling of the word.

Visual-Semantic Intervention: This intervention procedure combined aspects of 'Look Up Left', the Whole Word Method and Neurolinguistic Programming (NLP). Following visualisation exercises, flash cards were placed three feet in front, and one foot to the left, of the subject, as detailed in 'Look up Left'. By drawing the shape of a word onto squared paper, the subject was encouraged to focus on the word as a whole unit, which could be related to its spoken equivalent irrespective of internal structure. This aspect of the procedure was based on the Whole Word Method. The shape and semantic aspects of the stimulus words were then discussed as in NLP. Finally, the flash card was removed and, using the shape produced on the squared paper as a guide, the subject was required to write the word. If an error occurred, the flash card was reinstated and the correct spelling of the word copied.

Phase one of the intervention involved the instruction of list 1 via the phonics method to Group A and the instruction of list 1 by the visual-semantic method to Group B. Phase two represented the counterbalanced equivalent, the instruction of list 2 via a visual-semantic method to Group A, and via phonics to Group B.

The instruction of each list by a particular method was contained within the period of a week. Pre-testing was carried out on the Monday in order to determine a base line score. This was preceded by three, 15 minute sessions of individual tuition, on Tuesday, Wednesday and Thursday. Progress tests were conducted following the

first and second teaching sessions in order to document any differences in the rate of improvement. Post testing occurred on the Friday. A final test was carried out after a period of three weeks to investigate the extent to which acquired spelling knowledge was retained over time.

In addition to sex and group, other potential predictors of dyslexic's spelling ability were investigated. Dyslexic subjects were assessed on measures of verbal IQ, non-verbal problem solving and reading ability. Verbal IQ was assessed using the Mill Hill Vocabulary Scale (Raven et al, 1988) or The British Picture Vocabulary Scale (Dunn et al, 1982). Nonverbal IQ was assessed using either Raven's Standard Progressive Matrices (Raven et al, 1988) or the Matrix Analogies Test (Naglieri, 1985). Reading ability was measures by the Schonell Graded Reading Test (Schonell, 1976) or the reading subtest of the Wide Range Achievement Test (Jastak and Wilkinson, 1993). As different ability measures where used, all raw scores were converted into z scores. With regard to reading ability, reading age in months was used in the analysis.

2.9.4 Results

A mixed multi-factorial design with three independent variables was employed to determine possible interactions between method of instruction, sex and group. The method of instruction factor consisted of two conditions (phonics versus visual-semantic) and utilised a repeated measures design (subjects participating in both levels). The sex and group factor each comprised two independent conditions, male verses female and dyslexic verses non-dyslexic respectively. The dependent variable in each case was the number of words correctly spelt on post instruction testing relative to pre-testing (post minus pre intervention spelling score).

A three way analysis of variance indicated no significant interaction between method of instruction, group and sex (F=0.175, df =1 & 49, p=0.678). In addition, no two way interactions between either method and group (F=0.596, df =1 & 49, p=0.444), method and sex (F=2.731, df = 1 & 49, p=0.105) or group and sex (F=0.815, df =1 & 49, p=0.371) were identified (Table 2.25 presents summary results).

A comparison between groups needs to be treated with caution due to the relatively high pre-test scores produced by non-dyslexic subjects, reducing the scope within which these children could improve. As a result of this, dyslexic and non-dyslexic data were subsequently analysed separately using two-way mixed analyses of variance.

No significant interactions between method of instruction and sex were identified for either dyslexic (F=0.634, df =1 & 22, p=0.434) or non-dyslexic (F=2.559, df =1 & 27, p=0.121) groups. Main effects of method and sex were also non-significant for both dyslexics and non-dyslexics (p> 0.05 in all cases). Males failed to demonstrate superior performance when instructed by the visual-semantic method and no predisposition towards phonics instruction was apparent in the case of females.

Table 2.25: Mean improvement (standard deviation in brackets) of dyslexic and non-dyslexic males and females following each method of instruction.

	Dyslexics		**Non-dyslexics**	
	Males N=12	Females N=12	Males N=10	Females N=19
Phonics Improvement No. of words out of 15	5.83 (3.19)	6.92 (3.26)	4.70 (1.83)	4.68 (3.25)
Visual-semantic improvement No. of words out of 15	5.75 (4.58)	5.92 (3.06)	5.50 (1.72)	3.95 (2.46)

The rate at which dyslexics acquired spelling knowledge and the maintenance of that knowledge over time was also investigated, as were other potential predictors of dyslexic's spelling ability. Data pertinent to these investigations was available for 17 out of the 24 dyslexics. The remaining analyses refer to these individuals.

A three-way analysis of variance was used to examine the interaction between the rate of improvement produced by the different methods of instruction and sex. Within-group factors included method of instruction (phonics versus visual-semantic) and time of test (pre test, progress test 1, progress test 2 and post test). Sex represented the between subjects factor.

141

The results indicated a non-significant three-way interaction (F=0.504, df = 3 & 45, p=0.681). There was also no evidence of any two-way interactions between method and time (F=1.260, df = 3 & 45, p= 0.299), method and sex (F=0.494, df= 1 & 15, p= 0.493), or time and sex (F=0.198, df = 3 & 45, p=0.897). No main effects of method (F=0.662, df = 1 & 15, p=0.429) or sex (F= 26.301, df =1 &15, p=0.979) were apparent. However, a significant main effect of time of test was identified (F=35, df =3 & 45, p<0.001). Based on the results of a trend analysis, subjects demonstrated a linear improvement throughout the experimental procedure (F=39, df = 1 & 15. p<0.001).

A three-way analysis of variance was also used to examine the interaction between endurance of improvement, the different methods of instruction and sex. Within-group factors included method of instruction (phonics verses visual-semantic) and an endurance factor (performance on the post teaching assessment and performance on the final test three weeks later). Sex represented the between subjects factor.

The results indicated a non-significant three-way interaction (F=0.193, df = 1 & 15, p=0.666). There was also no evidence of any two-way interactions between method and endurance (F=2.294, df = 1 & 15, p= 0.151), method and sex (F<0.01, df = 1 & 15, p= 0.996), or endurance and sex (F=0.903, df = 1 & 15, p=0.357). No main effects of method (F=0.16, df = 1 & 15, p=0.900) or sex (F= 0.001, df =1 &15, p=0.981) were apparent. However, a significant main effect of the endurance factor was identified (F=22.337, df =1 & 15, p<0.001). Dyslexic's performance was significantly reduced on the final testing session relative to the post teaching session.

Changes in performance over time are shown in graphs 2.4 and 2.5 for males and females separately.

Graph 2.4: The mean number of words spelt correctly on pre, progress, post and final testing sessions for dyslexic males.
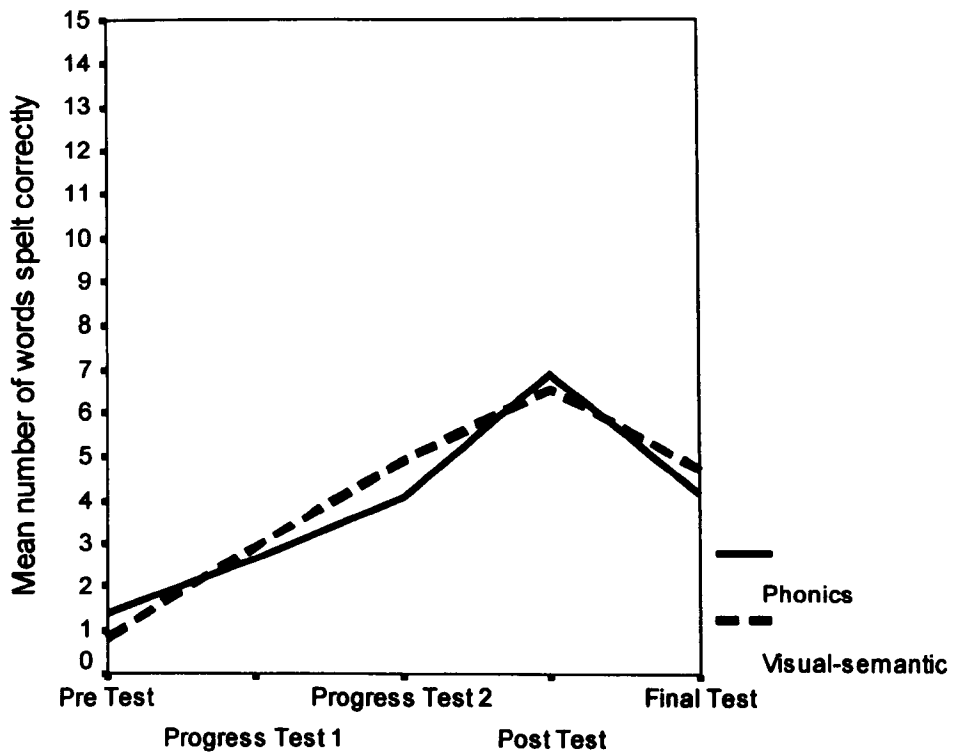
Graph 2.5: The mean number of words spelt correctly on pre, progress, post and final testing sessions for dyslexic females.
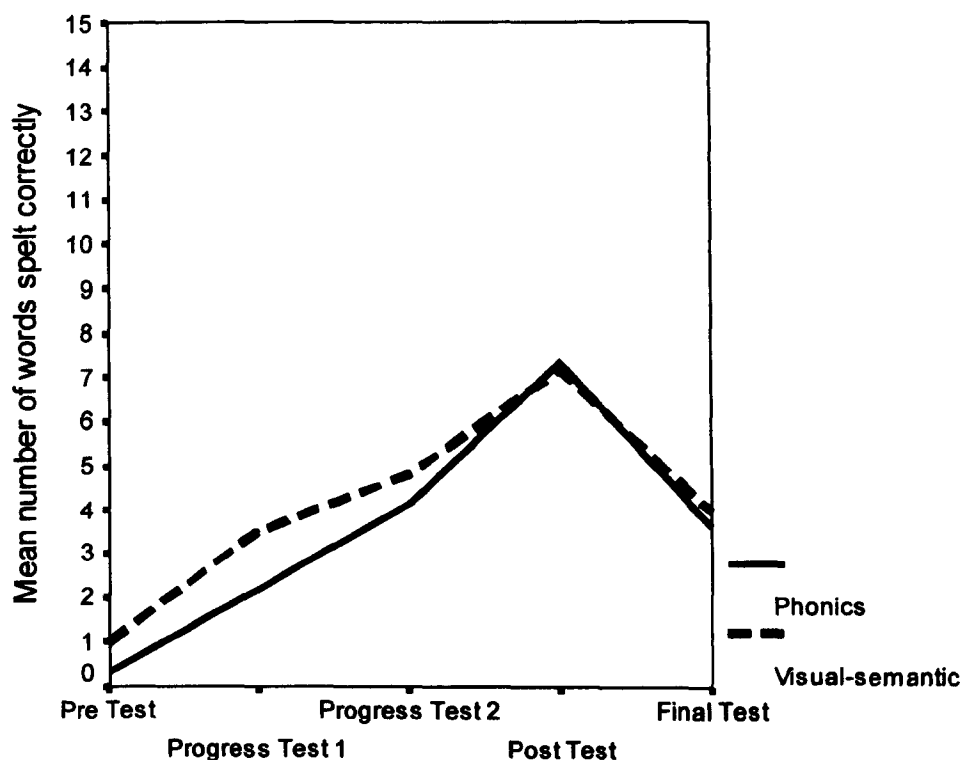
These results indicate that neither sex nor group (e.g. the presence or absence of dyslexia) contribute to an individual's preference for specific methods of spelling instruction. The final aim of the current study was to investigate other potential predictors of spelling improvement. To this end, Pearson Product Moment correlations were performed in order to identify any relationship between spelling improvement (following either phonics or visual-semantic instruction), reading age, verbal and non-verbal ability. The results of this analysis are detailed in Table 2.26.

Table 2.26: Correlations between spelling improvement following phonics and visual-semantic instruction and reading, verbal and non-verbal ability.

	Dyslexics (N=17)	
	Phonics improvement	**Visual-semantic improvement**
Reading age in months	0.474	0.591*
Verbal IQ (z score)	0.146	0.342
Non-verbal IQ (z score)	0.465	0.535*

** Correlation significant at the 0.01 level

* Correlation significant at the 0.05 level

A highly significant positive correlation (0.809**) was identified between the two improvement measures. A subject who benefited from phonics instruction also benefited from the visual-semantic instruction. None of the potential predictors were significantly correlated with advances in spelling following phonics instruction, although reading age and non-verbal IQ were approaching significance. Improvement in spelling following the visual-semantic method of instruction was significantly correlated with reading age and non-verbal ability. In order to determine which of the predictor variables (reading age, verbal and non-verbal ability) accounted for the most variance in spelling improvement following the visual-semantic intervention, a regression analysis was carried out using the Stepwise Method. The single best predictor of spelling improvement following visual-semantic instruction was reading ability, which accounted for approximately 35% of the variance (R^2=0.349, p=0.013) in spelling improvement.

2.9.5 Discussion

The results of the current study indicated that the type of intervention and the sex of the subject had a non-significant effect on the spelling improvement of dyslexics and non-dyslexics. Contrary to the remedial literature (e.g. Brooks and Weeks, 1999),

dyslexics did not show increased performance following visual-semantic instruction that was perceived as accessing their relative cognitive strengths and, consequently, as being more congruous with their learning style. The results were also inconsistent with the predictions derived from the sex differences literature. Whether dyslexic or non-dyslexic, females did not demonstrate greater improvements in spelling ability when instructed by the phonics method, nor was there evidence that males showed greater advances when instructed via a visual-semantic technique.

Additional analyses of dyslexic data, concerning the rate and endurance of spelling improvements also failed to identify an effect of sex. There was no evidence of differential rates of improvement for male and female dyslexics following either method of instruction. During the course of the study, both males and females showed equivalent linear improvements in spelling irrespective of the method of intervention. With regard to the endurance of spelling improvements, the dyslexic sample showed a significant reduction in the number of words spelt correctly when tested three weeks after the intervention. This reduction in performance occurred irrespective of the subject's sex or the method of instruction used. Although performance was still in advance of base-line measures (pre-test), scores were approximately halved on the final testing session relative to post instructional testing.

When other potential predictors of spelling improvement were investigated, a large relationship between the two measures of improvement was identified. A subject who benefited from phonics instruction also benefited from the visual-semantic instruction. Both improvement measures also correlated with non-verbal IQ and reading age (although this relationship was only significant for improvement following the visual-semantic intervention). As non-verbal IQ and reading age increased so did spelling improvement. Finally, a regression analysis indicated that reading ability was the best predictor of spelling improvement following visual-semantic instruction.

There are several potential mechanisms by which reading could benefit the acquisition of spelling. For example, the more an individual reads, the more knowledge of the printed word they acquire. The beneficial effects of exposure to

print are discussed in more detail in the following chapter, which also identified a relationship between reading and spelling ability in dyslexic adults.

2.9.6 Modifications and Future Research

Within this study comparisons of the dyslexics with their non-dyslexic peers had to be treated with caution, due to ceiling effects within the non-dyslexic data (i.e. the non-dyslexics achieved high pre-test scores which limited the extent to which they could improve). This created the impression that both groups made similar improvements of approximately 4 to 6 words. The non-dyslexics obtained pre-tests scores prior to both interventions of approximately 10 out of 15 and, therefore, they could only improve by 4 to 6 words. The dyslexics' pre-test scores were approximately 1 out of 15, leaving considerable room for improvement. Although the aim of the study was to focus on the effects of different remediation processes on the dyslexics, a design that employed both spelling age matched non-dyslexics (SA), who were given the same words as the dyslexics, and a group of chronological age matched non-dyslexics (CA), who were given harder words, would have allowed for a more accurate comparison of dyslexic and non-dyslexic performance.

Designs that incorporate both SA and CA controls can also be used to make the distinction between delayed or deviant development (Shaywitz, Escobar, Shaywitz, Fletcher and Makugh, 1992). If dyslexics perform like SA controls, (i.e. show similar levels, rate and endurance of improvement), but are underachieving relative to the CA controls, their spelling development is considered delayed. Their spelling behaviour is not different to that of normal children, it is just lagging behind that expected on the basis of their chronological age. If dyslexics performed differently to SA non-dyslexics (as well as CA non-dyslexics), we might conclude that dyslexics and non-dyslexics learn differently. For example, the dyslexics might not be able to apply their existing spelling knowledge, or make use of the various interventions in the same way as the SA group. Whether the different sexes would show differing profiles consistent with deviance or delay would also be interesting to consider.

The finding that the dyslexics did not show a preference for either intervention could reflect the level of difficulty of the stimulus words. As mentioned previously, on both

147

pre-tests the dyslexics scored approximately 1 out of 15. This increased to a mean of approximately 7 out of 15 on both post-tests. The current word lists proved very difficult for the dyslexics. Word lists consisting of easier words might have been more sensitive to differences in improvement. Instead of selecting words that reflected a spelling age one year above the dyslexics' chronological age, perhaps words reflecting a year in advance of the dyslexics (and SA controls) spelling age, would be have been more appropriate. Different words lists would facilitate the inclusion of easier words for the dyslexics and harder words for the CA non-dyslexics. The dyslexics could, therefore, be compared with their class mates, which is arguably of more practical use than comparisons with SA age controls. For example, comparing 11 year old dyslexics (year 6) with a group of eight to nine year olds (year 4) does not serve as an indication as to how these dyslexics learn in relation to their peers/class mates (e.g. other 11 year olds). Any variation in the acquisition and maintenance of spelling vocabulary between dyslexics and non-dyslexics has considerable implications for the instruction of dyslexics in mainstream schooling. From a practical perspective, the findings suggest that dyslexics would need to be given different spellings to their class mates in order to make the two groups comparable. In terms of their spelling ability, dyslexics are not comparable to their non-dyslexic classmates and should, therefore, not be expected to learn the same spellings.

Other potential predictors of spelling improvement following intervention could also be investigated. For example, in addition to reading ability, findings from various sections of the thesis suggest that orthographic and phonological processing, and information (e.g. ability to retain factual information and/or exposure to that information), also predicted dyslexics' spelling ability. Investigating whether these same factors would predict spelling improvements following intervention would provide further data on individual differences amongst dyslexics. Such predictors of spelling improvement following intervention could also be examined separately for males and females. Although the sexes did not respond differentially to the various interventions, different skills may predict the spelling improvements of males and females. For example, the findings reported in this thesis suggest that exposure to

print may predict the dyslexic females spelling gains, whilst phonological processing may predict the improvements made by the dyslexic males.

Chapter 2 examined the possibility that sex differences were contributing to the symptom diversity observed between dyslexics. The impact of sex differences (both behavioural and cognitive) on referral for assessment, the assessment process itself and subsequent remedial teaching was considered.

The extent to which behavioural differences between the sexes could contribute to the increased incidence of male referrals was examined. In accordance with referral bias theory males were rated as having more behavioural problems than females; however, they were also worse at reading. Either of these factors could, therefore, be contributing to the increased number of male referrals. The hypotheses that primary academic problems result in secondary behavioural/emotional difficulties, and that the nature of these difficulties varies according to sex were also investigated. Dyslexics were more hyperactive and emotional than the non-dyslexics and these behaviours appeared to be related to their reading ability (although not always in the predicted direction). However, it is unclear whether these behaviours are a response to reading failure or whether they in any way influence the referral process. Finally, these finding failed to support the hypothesis that males become more disruptive and females more withdrawn when they experience learning difficulties.

Subsequent analysis within Chapter 2 examined the extent to which the assessment process itself could account for the greater incidence of dyslexia in males. A female advantage was identified on 1 of the 7 subtests of the Bangor Dyslexia Test (months forwards). However, it is unlikely that such a minimal sex difference could bias the assessment process.

Study III compared the performance of dyslexic and non-dyslexic females on the ACID and AVID subtests. Differences were only identified on information. When the performance of male and female dyslexics on WISC-III^{UK} was compared in Study IV, females significantly outperformed males on digit span, coding and symbol search. The extent to which the ACID, AVID and SCAD profiles characterise the performance of dyslexic males and females was also investigated.

Digit span and coding were relative weaknesses for males whilst only digit span represented a relative weakness for females. These findings suggested that full ACID, AVID and SCAD profiles do not characterise the performance of dyslexics of either sex and are therefore are of limited diagnostic use.

The dyslexic females also outperformed the dyslexic males on measures of reading, spelling, phonological processing and the ACID and SCAD factor scores. The three factor scores (ACID, AVID and SCAD) were highly correlated with the reading and spelling ability of both groups; however, the extent to which they correlated with phonological processing ability was considerably reduced in females relative to males. Whereas phonological processing ability was predicted by vocabulary for both males and females, the predictors of reading and spelling differed across the groups. For dyslexic males phonological processing predicted reading and spelling ability whilst for females information was the single best predictor of literacy skills.

These findings suggest that dyslexic symptoms vary as a function of sex with dyslexic females showing potentially less severe and/or qualitatively different performance on several tasks. Males appeared to experience more severe deficits on the ACID, AVID and SCAD factors, which were found to vary in accordance with their phonological processing ability. These factor scores could therefore provide an indication of the severity of the phonological processing deficits experienced by dyslexic males, and consequently their reading and spelling ability.

The final section of Chapter 2 examined the response of dyslexics, non-dyslexics, males and females to different methods of spelling instruction (e.g. a phonics based method and a visual-semantic method). The results indicated that the type of intervention and the sex of the subject had a non-significant effect on the spelling improvements made by either group. Additional analyses of dyslexic data, concerning the rate and endurance of spelling improvements, also failed to identify an effect of sex or method of instruction. Rather than cognitive sex differences or the presence or absence of dyslexia, reading ability was found to predict the dyslexic's spelling improvement following intervention. One possible interpretation of these findings is that each dyslexic's learning style is individualised and cannot necessarily

be predicted on the basis of sex or the strengths and weaknesses that characterise all, or the majority, of those with dyslexia.

The finding that difficulties in one area related to dyslexia (reading) is predictive of variation in another (spelling) is not surprising. However, it does suggest that severity of difficulties may be an important factor in explaining individual differences amongst dyslexics and between dyslexics and non-dyslexics. An alternative explanation for the findings of the teaching study is that the dyslexics tested fell into discrete subtypes. Combining scores across subtypes may have masked differential outcomes that would have been apparent if the dyslexics had been split according to a subtyping procedure. Although the previous study used a sample size that was too small to divide into potential subtypes, this is another means of explaining differences amongst dyslexics. Indeed, in addition to sex differences, the subtype of dyslexia or severity differences in the underlying skills that predict dyslexic symptoms could represent other potential means of explaining the symptom diversity observed between dyslexics. These possibilities were investigated in Chapter 3.

3. INDIVIDUAL DIFFERENCES IN ADULT DYSLEXICS

3.1 STUDY VIa: Comparison of Dyslexic and Non-dyslexic Adults

3.1.1 Introduction

Dyslexia is generally perceived as a childhood developmental disorder, which predominantly manifests itself in difficulties with the acquisition of literacy. It is however, a life-long condition. Dyslexia-related problems often extend into adulthood (Beatton, McDougall and Singleton, 1997; Bruck, 1993b) with dyslexia being diagnosed amongst adults from varying social and educational backgrounds (eg, Miles, 1993; Patton and Polloway, 1996). While there are many studies investigating the diagnosis of dyslexia in children, there is a lack of research on the nature and identification of dyslexia amongst adults.

According to the National Working Party's Report on Dyslexia in Higher Education (1999) the occurrence of dyslexia in UK higher education institutions has substantially increased in recent years. It is now estimated that between 1.2 to 1.5% of students in higher education (HE) are dyslexic. Just over half declare their dyslexia on admission, whist the remaining students are identified as dyslexic during their time at university. The diagnosis of dyslexia typically results in certain recommendations designed to create a 'level playing field' for the dyslexic student. These could include special examination arrangements and additional support, both academic and financial. The purpose of these concessions is to allow the dyslexic to actualise their potential and not be disadvantaged relative to their non-dyslexic peers. HE institutions have both ethical and legal (Ability Discriminations Act, 1995, Code of Practise for the assessment of academic quality and standards in higher education: students with disabilities) responsibilities to ensure dyslexia is properly diagnosed and appropriate provisions are put in place.

As with children, the assessment of adults involves psychological testing and clinical judgement. The observation of test behaviour is particularly important when assessing adults who have potentially developed coping strategies that compensate for their difficulties (Beaton et al, 1997). For example, an adult dyslexic may

eventually produce the correct response, but the strategies employed, effort involved and/or time taken may indicate that a given task continues to represent an area of weakness. As well as a reliable diagnosis of dyslexia, an assessment should also provide an indication of the nature and severity of the individual's current strengths and weaknesses, the extent to which the weaknesses are likely to interfere with the student's ability to fulfil course requirements and what support/concessions would be most appropriate.

Research suggests that the neuropsychological aspects of dyslexia remain consistent throughout the life span (Bigler, 1992). For example, the profile of WISC subtest scores that typifies dyslexia in children is also evident in samples of adult dyslexics assessed on the WAIS. Alm and Kaufman (2002) identified the characteristic pattern of scores on Bannatyne's (1974) factors (spatial, verbal conceptualization, sequential and acquired knowledge), described in the previous chapter. Their sample of adult, Swedish dyslexics received their highest factor score on the spatial factor (picture completion, block design and object assembly) and their lowest score on the sequential factor (digit span, digit symbol and arithmetic). Furthermore, the ACID and AVID subtests (e.g. arithmetic, digit symbol/coding, information, digit span and vocabulary) represented the five lowest subtest scores obtained by their sample "reaffirming that this pattern is characteristic of adults with dyslexia and learning disabilities" (page 327). Similar results have been obtained by Katz et al, (1993), Cordoni et al, (1981), and Salvia et al, (1988). In accordance with the findings of the previous chapter, Vogel and Walsh (1987) remind us that samples such as those of Cordoni et al, (1981) were composed predominantly of males. Their findings may therefore not be applicable to dyslexics in general.

In addition to these characteristic information processing deficits, problems with phonology also extend into adulthood (Ben-Dror et al, 1991; Bruck 1990, 1992; Elbro et al, 1994; Gottardo et al, 1997; Snowling et al, 1997; Nicolson and Fawcett, 1997; Gallagher et al 1996). Bruck (1992) found that adult dyslexics failed to show age or reading level appropriate phonological awareness skills. Furthermore the reciprocal relationship demonstrated by her 'good readers' (e.g. phonological awareness increasing as a function of reading skill) was not apparent for the

dyslexics, whose phonological awareness appeared to have reached a developmental ceiling. Bruck (1992) maintained that the dyslexic's weak phonological awareness was not the result of a developmental delay in that they failed to show evidence of ever achieving appropriate levels of ability. Similarly, Snowling and Nation (1997) and Gallagher et al (1996) maintained that phonological deficits endure even when adult reading levels have been achieved. Howard and Best (1997) refer to case studies of adult dyslexics (e.g. Campbell and Butterworth, 1985; Funnell and Davison, 1989) whose word reading accuracy was determined to be normal even though phonological ability was impaired.

Bruck (1992) concluded that "phoneme awareness deficits characterize dyslexics at all ages" (page 882). Accordingly, Gottardo et al (1997) maintained that "it was vital to include a measure of phonological processing in an adult assessment battery" (page 52). Snowling et al (1997) found that non-word reading and the time taken to complete the spoonerisms task represented particularly powerful means of discriminating between dyslexic and non-dyslexic adults. Measures of spoonerisms accuracy, alliteration fluency and phoneme deletion were also determined to be diagnostically useful.

Although traditional conceptions of dyslexia have focused on reading difficulties, recent research suggests that poor single word reading accuracy in isolation does not represent a defining characteristic of dyslexia in children (Miles et al, 1998) and is not a sensitive measure for the identification of dyslexia in adults as it can be considerably improved through remediation. For example, Gallagher et al (1996) identified a group of 'high functioning' dyslexic students. These were intelligent individuals whose dyslexia was identified at an early age and who had received extensive remedial instruction. This group was considered 'compensated' in terms of their reading accuracy which fell within the average range, although the reading process was still timely and laborious. Similarly, Shaywitz (1996) maintained that "timed tasks reveal that decoding remains very laborious for compensated dyslexics; they are neither automatic nor fluent in their ability to identify words" (page 82). Gallagher et al (1996) assessed the dyslexic's absolute level of functioning on a measure of reading accuracy and their performance was considered average (with the

exception of one subject) in terms of the test norms. When diagnosing dyslexia, however, psychologists generally look for evidence of an ability / attainment discrepancy. In other words, the degree of discrepancy between the subject's literacy levels and the literacy levels predicted by their general intellectual ability. If single word reading accuracy represents one of the literacy measures with which IQ is contrasted, the ability of this procedure to identify dyslexia in adults may be compromised. For example, the ten cases of 'classic' phonological dyslexia described by Rack (1997) all manifest a "significant difference between intellectual ability level and spelling but not always reading".

Rack (1997) described the "life-long 'dyslexia syndrome' – a pattern of underlying cognitive strengths and weaknesses which has varying, but theoretically consistent, manifestations from pre-reader through to working adult" (page 75). The underlying information processing or cognitive deficits that characterise dyslexia appear enduring. The assessment of auditory short term memory, speed of information processing and phonology is thus applicable to children and adults. However, the expression of these underlying deficits in terms of overt literacy skills (e.g. the behavioural symptoms) potentially alters with age and circumstance. The phonological processing deficit that inhibited the acquisition of component reading skills in childhood may affect reading efficiency in adulthood.

The ability of compensated dyslexics to demonstrate 'normal' levels of reading accuracy results in the problem described by Beaton et al (1997) of "how to recognise dyslexia in otherwise literate adults" (page 1). Research suggests that perhaps greater emphasis should be placed on reading rate/efficiency, spelling or reading comprehension, rather than single word reading accuracy. For example, Everatt (1997) found that speeded non-word reading, spelling and reading comprehension (specifically a cloze procedure) represented effective means of distinguishing between dyslexic and non-dyslexic adults.

The National Working Party's Report on Dyslexia in Higher Education (1999) maintained that the diagnosis of dyslexia in adults has been confounded by the lack of appropriate test materials and the consequent misapplication of measures designed

for child samples. However, the diagnosis of dyslexia in adults may not be a case of simply creating age-appropriate versions of measures designed to assess children, but could potentially involve a shift in emphasis away from single word reading to other, more stable and enduring deficits.

Section 3.1, compares the performance of dyslexic and non-dyslexic adults on measures typically used to assess children and in some cases those which research has suggested could be used to assess dyslexic adults. Section 3.2 and 3.3 investigate individual differences in dyslexia. Section 3.2, examines whether it is possible to divide a sample of adult dyslexics into subtypes and investigates the meaningfulness and utility of any identified groupings. Finally, section 3.3, examines potential predictors of symptom severity amongst adult dyslexics.

3.1.2 Subjects

Forty-five dyslexic (24 males and 21 females) and 28 non-dyslexic (17 male and 11 female) volunteers participated in the study. All were students or recently graduated students. Dyslexic subjects were recruited via Dyslexia/Special Needs offices within universities in the South East. Non-dyslexic subjects were from the general population of students from similar institutions as the dyslexics.

Twenty nine dyslexics (15 males and 14 females) had been previously diagnosed at school or college. Sixteen (9 males, 7 females) were diagnosed during the current study via collaboration with an Educational Psychologist. Two of these individuals (one male and one female) had presented themselves as non-dyslexic/control subjects.

Volunteers were required to complete the University of Hull Student Information Sheet and the Adult Dyslexia Checklist.

The University of Hull Student Information Sheet inquired after the subject's perception of their difficulties, medical history (including childhood illnesses, auditory, visual and speech and language development), handedness, coordination,

previous educational assessments and Special Needs help received at school/college. Summary data derived from this questionnaire is presented below for descriptive purposes. Two individuals (1 dyslexic female and 1 non-dyslexic male) failed to complete/return this questionnaire, the following description is therefore based on responses from 44 dyslexics and 27 non-dyslexics.

Of the 44 dyslexic subjects who completed this form, the majority reported a history of difficulties with literacy acquisition (reading, writing and spelling) and persistent problems with these skills in adulthood. 34 maintained that they had been aware of these difficulties since primary school and seven since secondary school. The two dyslexics who presented as non-dyslexics did not report any difficulties and one dyslexic female chose not to respond to this question.

Thirty two out of 44 felt that their reading ability was worse than that of their peers, whilst 39 felt that their spelling ability was worse than that demonstrated by their contemporaries. Six dyslexic subjects (5 males, 1 female) had received Speech and Language Therapy during early childhood. 27 (out of the 44) had received Special Needs support at school. This ranged from: one-to-one tuition with a dyslexia specialist on a withdrawal basis; in class support or small group work with literacy/numeracy support teachers, class teachers or teaching assistants; extra time for exams or the completion of class/course work; the use of a word processor and, in one case a scribe. The majority (28 out of 44) reflected positively on their experiences at school.

Twenty eight of the 44 reported that other family members experienced similar literacy/cognitive difficulties. These were predominantly fathers, mothers and brothers.

Forty three out of the 44 dyslexic subjects reported their health, at the time of testing, to be very good or average. The one exception was a female who described herself as often tired and prone to illness. Ten (6 males and 4 females) maintained that they had experienced serious illnesses or medical problems during childhood. These included: asthma, pneumonia, whooping cough, anorexia, depression, grommets, a burst

appendix and an unspecified illness that resulted in one male dyslexic experiencing permanent deafness in his right ear. One of the 6 dyslexic males had suffered from deafness, asthma, protein alasy, a gut disorder, Stills Disease, whooping cough and Glandular Fever.

No gross visual difficulties were reported by the dyslexics, although 9 were short sighted and 12 were long sighted. Both groups wore glasses accordingly. When required to read at length, 21 (out of the 44) suffered from headaches, eyestrain and blurred vision, whilst 25 reported experiencing sensations of the print moving around during reading.

Six of the dyslexics felt that their hearing was unsatisfactory. This included the two dyslexic males previously described as suffering from auditory deficits. Additional unspecified difficulties referred predominantly to problems with speech perception, such as difficulties 'hearing people talk', 'hearing people talk against background noise' and problems 'hearing the end of words'.

Of the 44 dyslexics, 36 (22 males and 14 females) where right handed, 6 (1 male, 5 females) were left handed and 2 (1 male and 1 female) described themselves as 'equally good with both hands'. Thirty four felt that they were average to well co-ordinated, whilst the remaining 10 described themselves as generally quite clumsy.

None of the 27 non-dyslexic volunteers who completed the University of Hull Student Information Sheet reported a history of difficulties with the acquisition of literacy skills. Twenty five felt that their reading ability was better than, or equivalent to that of their peers, whilst 23 felt that their spelling ability was superior or equal to that demonstrated by their contemporaries. One individual voiced concerns regarding reading for meaning and his reading speed. His subsequent performance on the measure of reading comprehension failed to support these perceptions. Two (1 male and 1 female) had received psychological or educational assessments during childhood, one as a response to disruptive behaviour. Dyslexia was not diagnosed in either case.

Two non-dyslexic males had received Speech and Language Therapy during early childhood. In one instance this was a response to a hearing disability that was operated on at age 6. As a consequence of this hearing deficit, this individual also received some literacy support. This volunteer's hearing was satisfactory at the time of testing.

Only two other non-dyslexics received extra help at school. One male described being given 'extra spellings' and a female received some extra language tuition due to being from a bilingual family. The majority (23 out of 27) reflected positively on their experiences at school. One male and one female non-dyslexic had dyslexic siblings (a brother in both cases).

All 27 non-dyslexic subjects reported their health to be very good or average at the time of testing. Four reported serious illnesses or medical problems during childhood. These included: scarlet fever, kidney infections and acute appendicitis. One female had had three operations to correct for a lazy eye and one male (described previously) had had an ear operation.

Nine non-dyslexics wore glasses (7 were short sighted and 2 were long sighted). Although no glasses had been prescribed, the female with the corrected lazy eye reported poor long to mid distance vision and a squint. When required to read at length, 4 reported suffering from headaches, 8 from eyestrain, 7 from blurred vision and 4 experienced sensations of the print moving around.

In terms of auditory development, 23 out of the 27 described their hearing as satisfactory. The remaining 4 maintained that they were 'not sure', reporting unspecified difficulties pertaining to mild problems with speech perception (e.g. 'hearing people talk against background noise or when not looking directly at the person who is speaking').

Out of the 27 non-dyslexics, 25 (15 males and 10 females) where right handed and 2 (1 male, 1 female) were left handed. Twenty four felt that they were average to well co-ordinated, whilst the remaining 3 described themselves as generally quite clumsy.

Two dyslexic females failed to complete all of the measures included in the study and were consequently excluded from the ensuing analyses. The dyslexic group therefore, ultimately consisted of 43 (24 males and 19 females) subjects.

The Revised Adult Dyslexia Checklist (Vinegrad, 1994) required subjects to affirm or deny the existence of specific difficulties often associated with dyslexia (e.g. confusions in orientation, difficulties in sequencing and retaining verbally labelled information). The checklist consisted of 20 items on which subjects were required to respond yes or no. For example, "Do you find forms difficult and confusion?" The mean number of yes responses selected by the dyslexic group was 11.98 (standard deviation: 4.13) whilst the non-dyslexics selected, on average, only 2.96 (standard deviation: 2.74). In addition to significantly exceeding the number of yes responses selected by the non-dyslexics ($t=10.175$, $df=69$, $p<0.001$), the mean number of yes responses selected by the dyslexics was greater than 8, representing an extreme score indicative of dyslexia (Vinegrad 1994).

An independent samples t-test determined that on average, the dyslexic subjects (mean age: 22.65, standard deviation: 4.82) were younger than the non-dyslexics (mean age: 27.14, standard deviation: 3.39, $t=-4.612$, $df=69$, $p<0.001$), a factor that was controlled, where appropriate, in the reported analyses. The ratio of males to females did not differ significantly between the groups (dyslexics: 24:19; non-dyslexics: 17:11; $\chi^2_{(1)}=0.167$, $p=0.683$).

3.1.3 Measures and Procedures

Measures included in the analysis were based on those used to assess children and in some cases those which research has suggested could be used to assess adults. Two measures of non-verbal ability were administered to ensure that the dyslexic group fell within the average range and to facilitate comparisons with a group of non-dyslexics. Dyslexic and non-dyslexic adults were compared on several literacy measures including single word reading, spelling and reading comprehension. Measures of auditory short term memory, processing speed, vocabulary, phonological and orthographic processing were also included. The aim was to

161

determine the extent to which these measures represented continuing skill deficits for dyslexic adults. Dyslexic males were also compared to dyslexic females on those tasks that identified sex differences in Chapter 2. Further justification for the inclusion of individual tests is described in subsequent sections.

Subjects were tested on each measure, individually, in a quiet room. The order of presentation was pre-determined for all subjects at the start of the study (see Appendix B for the order used). This started with questionnaire details (see above), then assessed single word reading and spelling as well as text comprehension via standard measures used in the literature (see discussion below). Subtests taken from the Wechsler Adult Intelligence Scale - Revised were than administered, followed by additional regular, irregular and non-word reading tests. Finally, a series of phonological and orthographic tasks were administered. The order used ensured ease of administration (similar measures were presented together) but attempted to avoid confusion between tests.

3.1.3.1 Wechsler Adult Intelligence Scale – Revised

Subjects completed the Block Design, Picture Completion, Vocabulary, Digit Span and Digit Symbol subtests from the Wechsler Adult Intelligence Scale - Revised (WAIS-R: Wechsler, 1981). The raw scores produced on these tests were converted, using the test manual, into age appropriate scaled scores with a mean of 10 and a standard deviation of 3.

Block Design: The Block Design subtest was used to assess perceptual organisation, spatial visualisation and abstract reasoning. It required subjects to arrange coloured blocks in order to reproduce model patterns displayed on a card. There were nine patterns in total. The complexity of the pattern determined the time limit imposed for completion. Completion of the task within the given time limit earned the subject extra points in addition to those awarded for accuracy. The test was discontinued following three consecutive failures.

Picture Completion: This measure of visual perception assessed the subject's ability to make practical observations. It required subjects to indicate which important part was missing from a target picture. A total of 20 pen drawings were presented on individual cards (10 by 7 cm), with a maximum exposure time of 20 seconds per card. Items were scored either one or zero. The maximum raw score was 20. The test was discontinued following 5 consecutive scores of zero.

Vocabulary: The Vocabulary subtest was used to assess word knowledge. It required subjects to define words by providing synonyms, major uses, primary features or general classifications. Each word was presented verbally by the tester, a printed version remaining available to the subject at all times. Responses were scored either zero, one or two based on the marking criteria reported in the test manual. The maximum raw score on the 35 test items was 70. The test was discontinued following five consecutive scores of zero.

Digit Span (Digits forwards & Digits Backwards): Digit span assessed the recall of phonological information, attention and knowledge/use of rehearsal strategies. Subjects were required to repeat an arbitrary series of discrete numbers, verbally presented by the tester at a rate of one per second. For the forward task, subjects were required to repeat the series in the order presented, whereas for the backwards task the reverse order was required. For digits forwards item length ranged from three to nine digits. For digits backwards item length ranged from two to eight. In addition to STM capacity, digits backwards also required that the encoded information be reorganised and manipulated. Two trials were administered for each item, the test being discontinued following failure on both trials. The subject's raw score (out of a maximum of 28) was the sum of total digits forwards and total digits reversed. This combined score was then converted into an age appropriate scaled score.

Digit Symbol: This subtest was included as a measure of processing speed. It required participants to establish associations between symbols and digits on the basis of a provided code. This code was displayed directly above the test items. Subjects were required to correctly complete seven practice items to show that they

had understood task requirements. The number of associations, produced within 90 seconds represented the subject's raw score (out of a maximum of 93).

3.1.3.2 Reading and Spelling Tests

Single Word Reading (Wide Range Achievement Test, WRAT: Jastak and Wilkinson, 1993): Subjects were required to read 42 words of increasing complexity. The test was discontinued after 10 incorrect responses and/or omissions. The number of words pronounced correctly (plus 15 points awarded for letter reading) represented the subject's single word recognition score out of a maximum of 57.

Single Word Spelling (Wide Range Achievement Test, WRAT: Jastak and Wilkinson, 1993): This task assessed written encoding or spelling ability. Subjects were required to spell 40 words of increasing complexity. The test was discontinued after 10 incorrect responses and/or omissions. The number of words spelt correctly (plus 15 points awarded for letter writing) represented the subject's spelling score out of a maximum of 55.

Reading Comprehension: Subjects were required to read seven small passages of increasing complexity and answer five multiple-choice questions on each. The passages were available to the subjects throughout the entire testing session. Passages and questions were derived from the NFER Reading Comprehension Test (1975). As the UK norms were for children from the ages of 11.0 to 15.11, a 15 minute time limit was imposed for administration with adults. Comprehension was measured by the number of questions correctly answered out of a maximum of 35.

Castles and Coltheart's (1993) Task: This task required subjects to read three 30 item word lists. Lists were presented individually on a single sheet of paper with items arranged into three columns of ten. Subjects were instructed to read the items as quickly as possible from left to right. Lists one and two consisted of 30 words with regular (eg 'take', 'navy', 'radish') and irregular (eg 'sure', 'answer', 'colonel')

spelling patterns respectively. The third list consisted of 30 non-words (eg 'gop', 'phot', 'gurdet'). The number of letter strings pronounced correctly represented the subject's accuracy score out of a maximum of 30. The time taken to read the lists was used as a measure of reading speed.

Complex Non-word Reading Task: Subjects were presented with 26 novel letter strings (eg, 'feap', 'knoink', 'mibgus', 'depnonlel'). These non-words were derived from the literature (eg, Everatt, 1997; Rack et al, 1992; Snowling et al, 1997) and differed from those in the Castles and Coltheart (1993) task in that they were linguistically more complicated and harder to pronounce (ie, the inclusion of three syllable non-words, more digraphs and fewer non-words with close orthographic neighbours). Correct decoding was only possible via some level of grapheme to phoneme conversion. Subjects were instructed to read the list in their own time. The number of items decoded correctly was recorded and totalled.

3.1.3.3 Phonological Assessment Battery (PhAB)

Subjects completed the Spoonerisms, Verbal Fluency and Rapid Naming subtests from the PhAB (Frederickson, 1995).

Spoonerisms: The Spoonerisms subtest consisted of two semi-spoonerisms measures and a full spoonerism measure. The semi-spoonerisms tasks required subjects to replace the first sound of a word with a given sound ('fun' with a 'b' = 'bun') or with the first sound of a second word ('bull' with 'fed' = 'full'). The full spoonerisms measure involved the transposition of initial sounds from two words ('fed' and 'man' = 'med fan'). Phonological processing was measured as the number of correct responses out of a maximum of 40. No time constraints were imposed, although time taken to complete each section was recorded and totalled.

Semantic, Alliteration and Rhyme Fluency: For the semantic fluency task subjects were asked to name as many foods and animals as possible, thus providing an indication of the subject's ability to locate and retrieve semantic codes from long term memory. The alliteration and rhyme fluency tasks assessed the subject's ability

to use phonological codes to retrieve information from long term memory. Alliteration fluency required subjects to retrieve words that started with particular sounds (e.g. cat, came, kangaroo). Rhyme fluency required subjects to retrieve words that ended with particular sounds (e.g. cat, bat, fat, mat). The distinction between sounds and spelling patterns was stressed: for example, a number of different spelling patterns rhyme with the target word 'more' (eg, 'floor', 'or', 'war'). Homonyms were scored only once even when multiple meanings were provided, and non-words were marked as incorrect. Subjects were instructed to generate as many words as possible within 30 seconds. Two trials for each condition (semantic, alliteration and rhyme) were administered, with the average number of correct responses being calculated for each condition.

Rapid Naming: The rapid naming task involved the speeded retrieval of information from long term memory. This measure consisted of a picture naming condition and a digit naming condition. In both instances the subject was required to name a sequence of 50 stimuli as quickly as possible. The stimuli were either five common objects or the digits one through nine (bar seven) for the picture and digit naming tasks respectively. The order of presentation of the items was pseudo-random, avoiding sequences of the same object or runs of digits. The subject completed two trials for each condition. Although errors were noted, the time taken to complete each condition was used as the performance measure.

3.1.3.4 Orthographic Choice Task

An adaptation of Olson et al's (1985) Orthographic Choice Task (OCT) was used to investigate the ability to visually access a word entry in the lexicon. Subjects were presented with pairs of letter strings consisting of a correctly spelt word (e.g., 'goat') and a pseudohomophone (e.g., 'gote'). A pseudohomophone is a non-word that sounds like a real word. Generating pronunciations (phonological representations) would not distinguish between the correctly spelt words and pseudohomophones. Only knowledge of orthographic codes could be used to select the correct response. The subject's task was to proceed though a list of pairs selecting the correctly spelt words. Subjects were instructed to complete the task as quickly as possible. The

166

accuracy score represented the total number of correctly selected words out of a maximum of 52. The time taken to complete the task was also recorded.

3.1.4 Results

The performance of the dyslexics and non-dyslexics was compared on each of the measures, using independent samples t-tests (summary data are presented in Tables 3.1 through 3.4)

Due to the difference in average age found between the groups, analyses were also performed to statistically control this factor. Analyses of covariance, comparing the performance of the dyslexics and non-dyslexics with age as a covariate, were performed for all measures except the WAIS-R subtests, where scaled scores derived from age-based norms were used. For all measures, t-tests and ancovas produced the same results. For consistency of presentation, Tables 3.1 through 3.4 reports the results for the t-test analyses, ancova results can be found in Appendix C. Box plots showing the performance of dyslexics and non-dyslexics on each measure for which no age based norms were available can be found in Appendix D.

Table 3.1: Average scores (with standard deviations in brackets) and statistical comparisons (independent sample t-tests) for dyslexics and non-dyslexics on the WAIS-R subtests.

WAIS-R Subtests	Dyslexic N=43	Non-dyslexic N=28	t-test (df=69)
Block Design scaled score mean=10	13.53 (3.03)	14.07 (2.49)	-0.781 (p= 0.438)
Picture Completion scaled score mean=10	11.65 (2.27)	11.93 (1.78)	-0.546 (p= 0.587)
Vocabulary scaled score mean=10	10.88 (1.73)	13.75 (1.88)	-6.585 (p<0.001)
Digits Span scaled score mean=10	9.21 (2.45)	12.54 (2.69)	-5.375 (p<0.001)
Digit Symbol scaled score mean=10	8.93 (2.50)	12.46 (1.73)	-6.520 (p<0.001)

Graph 3.1: Mean subtest scores for dyslexics and non-dyslexics on the five WAIS-R subtests. Average range (7 to 13) is shaded in grey.
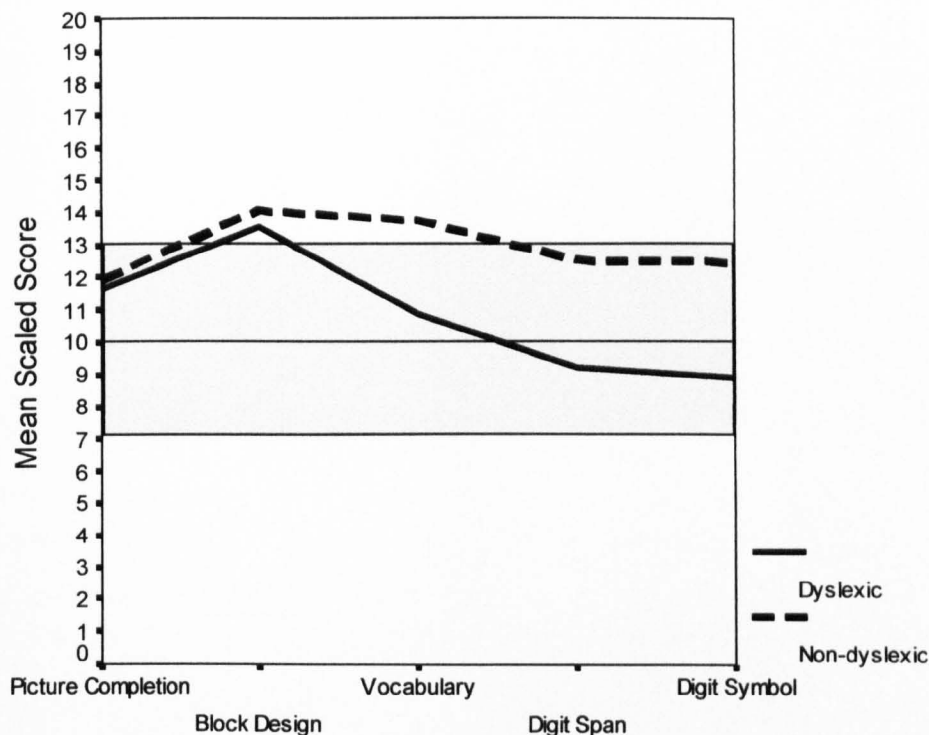
Reference to Table 3.1 shows that no differences were identified between the groups on Block Design or Picture Completion. The groups can therefore be considered as matched with regard to non-verbal ability. Both dyslexics and non-dyslexics obtained high average scores on picture completion and scored above the average range on block design. The non-dyslexics significantly outperformed the dyslexics on the remaining three WAIS-R subtests. The mean performance for the non-dyslexics on vocabulary was superior, exceeded the average range. For the dyslexics, however, mean performance was average. On both digit span and digit symbol the performance of the non-dyslexics was high average. The mean performance of the dyslexics was not only significantly weaker than that of the non-dyslexics, it was also relatively weak with regard to age based norms falling within the low average range on both tasks.

Table 3.2: Average scores (with standard deviations in brackets) and statistical comparisons (independent sample t-tests) for dyslexics and non-dyslexics on the reading and spelling tasks.

Reading & Spelling Tests	Dyslexic N=43	Non-dyslexic N=28	t-test (df=69)
WRAT Single Word Reading* No. correct out of 57	42.37 (4.72)	50.86 (2.97)	-9.300 (p<0.001)
WRAT Spelling* No. correct out of 55	36.00 (6.60)	46.64 (2.64)	-9.476 (p<0.001)
Reading Comprehension No. correct out of 35	16.42 (6.16)	26.29 (4.14)	-7.443 (p<0.001)
Regular Word Reading* No. correct out of 30	28.33 (2.22)	29.93 (0.26)	-4.680 (p<0.001)
Regular Word Reading Speed* Time in seconds.	24.43 (16.85)	12.57 (2.04)	4.565 (p<0.001)
Irregular Word Reading* No. correct out of 30	23.14 (4.67)	28.32 (1.54)	-6.738 (p<0.001)
Irregular Word Reading Speed* Time in seconds.	35.12 (25.58)	16.39 (3.61)	4.728 (p<0.001)
Non-word Reading* No. correct out of 30	19.53 (6.07)	27.32 (2.86)	-7.265 (p<0.001)
Non-word Reading Speed* Time in seconds.	50.21 (30.89)	20.89 (5.18)	6.093 (p<0.001)
Complex Non-word Reading* No. correct out of 26	16.37 (4.30)	22.11 (2.51)	-7.084 (p<0.001)

* Equal variance not assumed, therefore df values vary from 69 in accordance with procedures in SPSS version 10.

For WRAT, reading and spelling age based norms (mean of 100 and standard deviation of 15) were available for adults. Although the mean standard scores for both dyslexics (mean: 91.47, standard deviation: 9.39 for reading and mean: 88.51, standard deviation: 13.52 for spelling) and non-dyslexics (mean: 107.36, standard deviation: 6.90 for reading and mean: 109.89, standard deviation: 6.06 for spelling) were within the average range, the non-dyslexics scored above the mean whilst the

performance of the dyslexics was low average. When the average performance on block design and picture completion was converted into a scale that varied around 100 it represented a standard score of approximately 113 for the dyslexics and 115 for the non-dyslexics. When the discrepancy between estimated non-verbal functioning and performance on the reading and spelling tasks was determined, the dyslexics, but not the non-dyslexics, were found to be significantly underachieving.

For the NFER reading comprehension test, the complex non-word reading task and Castles and Coltheart's (1993) reading tasks no adult norms were available. If the performance of the non-dyslexics is used to infer the level of functioning expected of individuals of a particular age (controlled for statistically) and non-verbal ability, the dyslexics are significantly underachieving on all measures (see also Appendix C for ancova results).

The performance of the non-dyslexics was subject to considerable ceiling effects on Castles and Coltheart's (1993) reading tasks. On the measure of regular word reading 93% of the non-dyslexics scored 30 out of 30, the remaining 7% scoring 29. The dyslexics also scored quite highly on this measure, with approximately 95% achieving a score of 25 or over. On the irregular word reading task the majority (96%) of non-dyslexic subjects scored 25 plus, the lowest score obtained by a non-dyslexic was 24. Just under half (approximately 49%) of the dyslexics scored 25 or over on the measure of irregular word reading. The minimum score obtained by a dyslexic was 10. On the measure of non-word reading approximately 83% of the non-dyslexics scored 25 plus, 20 points representing the lowest score. Only 33% of the dyslexics achieved a score greater than 25, with a score of 8 representing the weakest performance on this measure. The time taken to complete these tasks (i.e. reading speed) also varied far more within the dyslexic group.

Although none of the non-dyslexics scored full marks (26 out of 26) on the complex non-word reading task, the majority (82%) scored 20 or above, 17 representing the lowest score. The performance of the dyslexics was far more variable ranging from a minimum of 6 to a maximum of 23. Only 23% of the dyslexics scored 20 points or above.

Table 3.3: Average scores (with standard deviations in brackets) and statistical comparisons (independent sample t-tests) for dyslexics and non-dyslexics on the PhAB subtests.

PhAB Subtests	Dyslexic N=43	Non-dyslexic N=28	t-test (df=69)
Spoonerisms Accuracy* No. correct out of 40	27.47 (8.99)	35.93 (3.63)	-5.523 (p<0.001)
Spoonerisms Speed* Time in seconds	306.44 (140.01)	139.71 (40.28)	7.355 (p<0.001)
Semantic Fluency No. of words generated	15.03 (3.56)	20.44 (4.45)	-5.660 (p<0.001)
Alliteration Fluency No. of words generated	8.13 (2.45)	11.34 (3.12)	-4.838 (p<0.001)
Rhyme Fluency No. of words generated	6.47 (2.52)	9.45 (2.78)	-4.663 (p<0.001)
Picture Naming* Time in seconds	38.48 (8.22)	29.38 (3.19)	6.546 (p<0.001)
Digit Naming* Time in seconds	22.89 (6.44)	14.88 (3.28)	6.901 (p<0.001)

* Equal variance not assumed, therefore df values vary from 69 in accordance with procedures in SPSS version 10.

As with the reading comprehension, regular, irregular and non-word reading tasks no adult norms were available for PhAB. The non-dyslexics significantly outperformed the dyslexics on all measures. On the spoonerisms task, approximately 18% of the non-dyslexics and only 2% of the dyslexics scored full marks. Twenty one percent of the dyslexics scored less than half marks (less than 20), whereas the lowest score achieved by a non-dyslexic was 27. Variability within the dyslexic group was consequently greater than that within the non-dyslexic sample. The non-dyslexics also performed the spoonerisms task significantly faster than the dyslexics who took, on average, over two minutes longer than the non-dyslexics.

On the fluency task, the non-dyslexics generated significantly more words than the dyslexics for all categories and on both rapid naming measures the non-dyslexics named the target items significantly faster than the dyslexics.

Table 3.4: Average scores (with standard deviations in brackets) and statistical comparisons (independent sample t-tests) for dyslexics and non-dyslexics on the Orthographic Choice Task.

Orthographic Choice Task	Dyslexic N=43	Non-dyslexic N=28	t-test (df=69)
OCT Accuracy* No correct out of 52	46.58 (6.36)	51.79 (0.42)	-5.352 (p<0.001)
OCT Speed* Time in seconds	103.65 (79.47)	51.04 (9.00)	4.299 (p<0.001)

* Equal variance not assumed, therefore df values vary from 69 in accordance with procedures in SPSS version 10.

The non-dyslexics significantly outperformed the dyslexics with regard to the number of correct responses scored on the OCT task. Some 14% of the dyslexics scored full marks compared to 79% of the non-dyslexics. The remaining 21% of the non-dyslexics scored 51 out of 52 whereas the minimum score obtained amongst the dyslexic group was 24. The non-dyslexics, therefore, demonstrated a ceiling effect, whereas the performance of the dyslexics was far more variable. The non-dyslexics also outperformed the dyslexics with regard to the speed of orthographic processing. The dyslexics, on average, took nearly a minute longer to complete the task than the non-dyslexics. Variance within the dyslexic group was again far greater than that observed within the non-dyslexics.

The non-dyslexic adults significantly outperformed the dyslexics on measures of vocabulary, auditory short term memory and processing speed. The performance of the non-dyslexics was also significantly in advance of the dyslexics on all measures of literacy (including reading, spelling and reading comprehension), phonology and orthography. With the exception of the two measures of non-verbal IQ, all of the

tasks used in the current study represent efficient means of distinguishing between typical dyslexic and non-dyslexic adults.

The performance of the dyslexic males and females was also compared (using independent samples t-tests) on those measures on which a sex difference was identified in Chapter 2 (summary data presented in Table 3.5).

Table 3.5 Average scores (with standard deviations in brackets) and statistical comparisons (independent sample t-tests) for dyslexic males and females on digit span, digit symbol, reading, spelling and spoonerisms.

	Males N=24	Females N=19	t-test (df=41)
Digits Span scaled score mean=10	9.29 (2.76)	9.11 (2.08)	0.244 (p=0.808)
Digit Symbol scaled score mean=10	8.50 (2.28)	9.47 (2.72)	-1.277 (p=0.209)
WRAT Single Word Reading No. correct out of 57	42.38 (4.69)	42.37 (4.89)	0.004 (p=0.996)
WRAT Spelling No. correct out of 55	34.54 (6.90)	37.84 (5.86)	0.499 (p=0.104)
Spoonerisms Accuracy No. correct out of 40	26.50 (8.21)	28.68 (9.97)	-0.788 (p=0.435)
Spoonerisms Speed Time in seconds	299.71 (127.1)	314.95 (157.99)	0.523 (p=0.728)

No differences were identified between the performance of the dyslexic males and females on any of these measures. In accordance with the findings of Chapter 2, females obtained slightly higher scores on digit symbol (i.e. coding), WRAT spelling and spoonerisms accuracy. However, these differences were minimal and non-significant. Although males completed the spoonerisms task approximately 15 seconds faster than the females, this differences was also non-significant.

On all of the measures included in Table 3.5 the non-dyslexics significantly outperformed the dyslexics. Additional comparisons were conducted in order to determine if this was the case when the sexes were analysed separately. Independent samples t-tests were used to compare the performance of the dyslexic and non-dyslexic males and the performance of the dyslexic and non-dyslexic females on digit span, digit symbol, reading, spelling and spoonerisms. Results indicated that the non-dyslexics continued to outperform the dyslexics irrespective of sex (all $p<0.05$).

Miles (1993) suggests that "adults with dyslexia may not show evidence of poor performance on untimed single word reading tests" (Everatt 1997, page 13) and Gallagher et al's (1996) 'compensated' dyslexics provide support for this hypothesis. A compensated dyslexic was defined by Gallagher et al (1996) as a "high functioning dyslexic - whose reading ability had improved so that it was now within one standard deviation of the normal population mean" (page 499). In a scale that varies around a mean of 100 with a standard deviation of 15, the average range is between 85 and 115. When adhering to such a definition the dyslexics within the current study could also be considered as compensated (see Table 3.6). When the results of the current study were compared to those of Snowling et al (1997), and Gallagher et al (1996) (see Table 3.6) only Snowling et al's dyslexics appeared to be underachieving in reading and spelling. For example, their reading ability was -1.03 standard deviations below the mean (e.g. just outside the average range) and their spelling score was over one and half standard deviations (-1.76) below average.

Table 3.6: Mean standards scores (with standard deviations (sd) in brackets) produced by Snowling et al's (1997), Gallagher et al's (1996) and the current studies dyslexics for WRAT reading and spelling

Dyslexic Samples	WRAT Reading	WRAT Spelling
Current study N=43 (mean age 22.65, sd=4.82)	91.47 (9.39)	88.51 (13.52)
Snowling et al (1997) N=14 (mean age 25.5, sd=3.9)	84.5 (10.6)	73.5 (14.6)
Gallagher et al (1996) N=16 (mean age 18.43, sd=1.10)	103.94 (8.54)	96.06 (7.37)

In all three studies (current study, Snowling et al, 1997, and Gallagher et al, 1996) the reading and spelling scores of the dyslexics were significantly worse than that of an age equivalent group of controls matched for non-verbal ability or academic achievement. Furthermore, when the reading and spelling ability of the dyslexics in the current sample was compared with an approximate measure of underlying non-verbal ability, the dyslexics were determined to be underachieving. It appears therefore, contrary to the position of Miles (1993) that reading accuracy represents a continuing area of weakness for adult dyslexics.

In all three studies, the non-dyslexics significantly outperformed the dyslexics on measures of non-word reading, spoonerisms speed and digit naming speed. In the current study and Snowling et al (1997), the non-dyslexics also outperformed the dyslexics on spoonerisms accuracy (Gallagher's groups did not differ with regard to accuracy only speed). In accordance with the current study, Snowling et al's (1997) groups also differed (in favour of the controls) on measures of alliteration and semantic fluency (although not rhyme fluency), digit span and vocabulary (although not block design). As mentioned previously, the largest effect sizes were identified on measures of non-word reading and spoonerisms speed. In order to compare the magnitude of the differences between the dyslexics and non-dyslexics across the two studies, effect sizes were determined (using the standard deviation of the non-

dyslexics as in Snowling et al, 1997) for the complex non-word reading task and spoonerisms speed. An effect size of 2.29 relating to complex non-word reading was determined (the effect size derived from this measure needs to be treated with caution due to ceiling effects within the non-dyslexic data). This is slightly less than the 3.63 identified by Snowling et al (1997). The effect sizes relating to spoonerisms speed appeared reasonably consistent (4.14 for the current study and 3.91 for Snowling et al, 1997). Due to the ceiling effects observed in the non-dyslexic data it was not possible to produce effect sizes for all the measures used in the current study. However, on speed measures where no time constraints were imposed (e.g regular, irregular and non-word reading and the OCT) large effects sizes were identified.

Poor performance by the dyslexics on the semantic fluency task is inconsistent with the child data reported in the PhAB manual (Frederickson, Frith and Reason, 1996). No significant differences were identified between dyslexic children (age ranging from 8.00 to 12.11 years) and the PhAB's standardization sample. In an initial assessment of the PhAB's 'theoretical and practical utility', Gallagher and Frederickson (1995) did find that 10 year old good readers outperformed poor readers on the semantic fluency task, whereas no differences were identified between 6 and 8 year old good and poor readers. The authors attributed this trend (which would be considerably increased in an adult sample) to the 'Matthew Effect' (Stanovitch, 1986). Dyslexic and non-dyslexic adults could potentially have experienced years of differential exposure to print, resulting in a discrepancy between their levels of word knowledge. This 'long term consequence' of poor reading could affect the manifestation of dyslexia in adults.

The results suggest that dyslexic adults, even those who have been relatively successful in education in terms of reaching entry requirements for higher education courses, will continue to show evidence of poor literacy, phonological and orthographic processing skills compared to their higher education non-dyslexic peers.

3.1.5 Modifications and Future Research

A potential problem with Study IVa was that a number of the measures investigated were designed for use with children. As a result the non-dyslexics (and in a few instances the dyslexics) were achieving at ceiling on a number of tests. As a consequence, it was not always possible to determine effect sizes. The magnitude of the differences between the groups across different measures could therefore not be compared. A pilot study would have checked the appropriateness of the measures for an adult sample. However, the research does not appear to have been overly compromised by these ceiling effects as the measures were still able to distinguish between the dyslexics and non-dyslexics.

3.2 STUDY IVb: Subtypes

3.2.1 Introduction

In an attempt to understand the diverse symptomology within dyslexic populations, many researchers have postulated the existence of distinct subtypes. According to Watson and Willows (1993) and Rispens et al (1994) subtyping systems can be derived from clinical and statistical models. Clinical or inferential methods involve clinicians examining behaviour (e.g. reading and spelling performance) in order to subjectively group individuals who show similar patterns of performance. The majority of early subtyping studies employed this method and most identified auditory and visual subtypes. For example, Johnson and Myklebust (1967) identified auditory and visual dyslexics as did Ingram, Mason and Blackburn (1970) in this instance referred to as audio-phonic and visuo-spatial dyslexics. Both Boder (1970, 1971) and Thomson (1982) identified auditory, visual and mixed subtypes of dyslexia following an analysis reading and spelling errors. Boder's (1970, 1971) were referred to as dysphonetic and dyseidetic, whilst Thomson's (1982) were labelled auditory-linguistic and visuo-spatial. Mattis, French, and Rapin (1975) also identified three distinct subtypes that existed in similar numbers across groups of acquired and developmental dyslexics. Mattis, French, and Rapin's (1975) classification consisted of a group with language/auditory deficits, a group who manifested motor dysfunctions including problems with speech articulation and 'graphomotor discoordination' and a subtype with visuo-spatial perceptual disorders.

The auditory, audio-phonic, dysphonetic, and language disordered dyslexics all exhibited deficits in phonological processing (e.g auditory discrimination & sound blending). The visual, visuo-spatial, dyseidetic and visuo-perceptual dyslexics showed poor visual perception and visual discrimination, orientation difficulties (e.g. transposal, inversion and reversal errors) and problems with the visual recognition of whole words.

Although, these clinical subtyping systems identified a visual subtype, the incidence of visual difficulties was reduced relative to the occurrence of phonological deficits. For example, the visual-spatial subtype identified by Ingram, Mason and Blackburn

179

(1970) constituted only 21% of their sample. Similarly only 10% of Boder's (1970, 1971) dyslexics were classified as dyseidetic readers and spellers (as apposed to the 63% classified at dysphonetic). Finally, only 16% of Mattis, French, and Rapin's (1975) sample were visuo-perceptual dyslexics compared to the 38% classified as language disordered.

Satz and Morris (1981) maintained that the "visual inspection of complex data sets [was] limited and may not generate optimal and valid subgroups" (page 122). As a means of making these classifications more objective, subsequent empirical models employed statistical techniques such as cluster analysis or factor analysis to group individuals according to patterns of performance on various cognitive and language based tasks. For example, Doehring and Hoshko (1977) divided their sample of poor readers into three subgroups by factor analyzing the results of various measures of rapid reading skills. The first group showed poor oral word reading, the second presented difficulties with making auditory-visual letter associations, whilst the third was characterised by slow auditory-visual matching of words and syllables. This final group was considered analogous with the auditory/phonological subtypes described above.

Data from the Florida Lonitudinal Project has also been applied to the study of subtypes (Satz and Morris, 1981 and Morris and Satz, 1984 – cited in Watson and Willows, 1993). Two hundred and thirty unselected school children were grouped using cluster analysis into nine clusters on the basis of their WRAT reading, spelling and arithmetic scores. The two groups with the lowest WRAT scores (consisting of 89 boys) were considered learning disabled. The performance of these boys on various neuropsychological tests was subsequently examined, again using cluster analysis, and five subtypes identified. Two groups representing approximately 46% of the sample were categorised according to their language impairments. The first showed general verbal deficits and the second specific verbal naming deficits. The visual-spatial subtype constituted approximately 26% of the sample and the mixed-global subtype (impaired on all measures) 11%. The fifth subtype referred to as 'unexpected' showed no impairment on any tasks and constituted approximately 14% of the sample. The remaining three percent were outliers. These resultes were

replicated by Van der Vlugt and Satz (1985) who found that 18% of their sample of learning disabled Dutch children showed visual perceptual difficulties, whilst 82% showed verbal deficits.

Lyon and Watson (1981) also used cluster analysis to group 11 to 12 year old poor readers into subtypes on the basis of their performance on 8 psycholinguistic, neuropsychological and reading tasks. Six subtypes distinguished by different language and perceptual deficits were identified. These included linguistic, visual and mixed groups. Contrary to previous findings the group with visuo-perceptive deficits constituted 34% of the sample, representing the largest subgroup. Lyon and Watson (1981) and Lyon (1985a, 1985b) provided one of the first investigations into what Fletcher et al (1998) referred to as the "subtype by treatment interaction" (page 106) e.g. the effectiveness of using different remedial programmes to teach different subtypes of poor readers. For example, subtypes with either linguistic deficits or mixed linguistic and visual-memory deficits did not respond as favourably to an alphabetic/phonic intervention as the subgroup with only visual memory or visual-spatial difficulties.

Cluster analysis was also used to divide samples of reading/learning disabled children into subtypes by Watson, Goldgar and Ryschon (1983) who identified three subgroups on the basis of performance on various linguistic and cognitive tasks. Similarly, McKinney, Short and Feagans (1985) identified six 'perceptual and linguistic' subtypes and Korhonen (1988, cited in Watson and Willows, 1993) identified four 'neuropsychological' subtypes. As with other studies these classifications included groups with specific visual and specific verbal weaknesses. The visual subtypes were described as having visual, perceptual and visuo-motor processing deficits, whilst the verbal subtypes had general and/or specific language/linguistic deficits.

Petrauskas and Rourke (1979) identified three reliable subtypes of poor readers using factor analysis. The largest group which had a male to female ratio of three to one manifest verbal deficits and was considered analogous to the auditory/phonological subtypes described previously. The second group (with a male to female ratio of

12:1) showed evidence of sequencing difficulties including the ACID pattern of scores on WISC-R. Petrauskas and Rourke's (1979) third subtype was described in accordance with Mattis, French, and Rapin's (1975) subtype with motor dysfunctions. Thomson et al (1980, cited in Thomson, 1990) also used factor analysis to divide a group of dyslexic children into seven subtypes. Although the majority of these described various linguistic/verbal deficits, a visuo-spatial subtype was also identified.

In addition to clinical and statistical methods, Rispens (1994) also describes rationally defined and developmental classification systems. Rationally, or theory, defined subtypes group individuals that share certain characteristics. Bakker's (1979) perceptual (P-type) and linguistic (L-type) dyslexics are an example of this approach. Bakker and Moerland (1981) maintained that perceptual dyslexia resulted from the persistent use of right hemisphere, visuospatial reading strategies whilst linguistic dyslexia followed the untimely use of left hemisphere linguistic approaches to reading. Due to sex related differences in the learning to read process, these authors suggested that perceptual dyslexia would be more common in males, whilst linguistic dyslexia would be more typical of females.

Finally, developmental approaches classify individuals according the stage of literacy development at which they were potentially arrested. An example of this type of classification is Frith's (1985) Type B spellers whose symptoms were attributed to a lag during the early orthographic stage of literacy development. Vernon (1977, 1979) also described different subtypes of poor readers according to the stage of reading acquisition at which they had 'broken down'. Vernon described five subtypes. The first two were characterised by difficulties with the analysis of complex visual shapes and the analysis of whole words into phonemes. The third subtypes experienced difficulties making regular grapheme phoneme associations, whilst the forth had problems with irregular grapheme phoneme associations and complex orthography. The final subtype had difficulties assembling words into sentences and phrases.

Following their investigation into the 'clinical relevance' of dyslexia subtypes Rispens et al (1994) made the observation that irrespective of the classification method (e.g. clinical or statistical) "word identification ability is considered as one of the relevant variables in the search for subtypes" (page 76). These authors identified what they referred to as a 'common dichotomy' between whole word or Chinese readers and recoding readers or Phoenicians. Whole word readers experienced problems with phonological decoding and consequently relied on whole word orthographic reading strategies. Conversely, recoding readers had difficulty accessing their sight vocabulary and therefore depended on phonological decoding. Rispens et al (1994) draws a superficial parallel between Boder's (1970, 1971) dysphonetic dyslexics, Bakker's (1979) L-type dyslexics, Mitterer's (1982) whole word readers, Lovett's (1984) accuracy disabled readers and Van der Leij's (1983, cited in Rispens et al, 1994) readers who employed a 'guessing strategy'. All of these subtypes, demonstrated phonological decoding difficulties. Similarly, Boder's (1970, 1971) dyseidetic dyslexics, Bakker's (1979) P-type dyslexics, Mitterer's (1982) recoding readers, Lovett's (1984) rate disabled readers and Van der Leij's (1983, cited in Rispens et al, 1994) readers who employed a 'spelling strategy', appeared to rely on phonological reading mechanisms.

Subtypes characterised by the use of different reading mechanisms are also apparent in samples of acquired dyslexics. As mentioned previously (see Chapter 1), acquired dyslexia is a neurological condition resulting in literacy-related difficulties following injuries to the brain (Beauvios and Derousne, 1979; Coltheart, Patterson and Marshall, 1987; Marshall and Newcombe, 1973; Patterson, Marshall and Coltheart, 1985).

A variety of different types of acquired dyslexia have been identified. As these subtypes are caused by localised brain injury, their effects on the reading process can be quite specific. Similarly, the symptoms manifested by an acquired dyslexic will depend on which aspect of the reading process has been selectively compromised. Although several different subtypes of acquired dyslexia have been proposed to equate to developmental dyslexia counterparts (eg, Jorm, 1979; Rayner, Murphy, Henderson and Pollatsek, 1989), it is the phonological and surface subtypes that

appear to correspond to developmental whole word readers and recoding readers respectively.

The phonological/surface classification system was first considered within the framework of the Dual Route Model and, subsequently, by connectionist theories (see reviews in Ellis, 1984; 1993). According to the Dual Route Model, successful reading depends on the interaction of sublexical and lexical procedures. Only when both of these procedures are functioning adequately is an individual able to read all forms of text. The sublexical procedure decodes novel letter strings via grapheme/phoneme correspondence rules that exist in alphabetic writing systems. Consequently, this procedure can only be applied successfully to the pronunciation of words that conform to these rules. This procedure involves the division of written words into graphemes (letters or groups of letters), the mapping of sounds or phonemes to those graphemes, and the blending of the sounds together to produce a pronunciation. A break within the sublexical route results in the subtype of acquired dyslexia referred to as phonological dyslexia. Individuals who have acquired phonological dyslexia experience difficulties decoding unfamiliar words since the only way to read a novel letter string that is not represented in the sight vocabulary is to implement some process of decoding. The symptom most often associated with phonological dyslexia is, therefore, a difficulty with the reading of non-words or nonsense words like 'latsar' or 'polmex'.

The second pathway for accessing a pronunciation (the lexical procedure) treats written words as whole units. The visual or orthographic representation of a word is used to recover the connected pronunciation stored in the mental lexicon. This pathway represents the mechanism by which the sight vocabulary is accessed. Through this route, individuals are able to recognise words they have seen before and pronounce them without having to decode them. A break within the lexical procedure results in a subtype of acquired dyslexia referred to as surface dyslexia. Surface dyslexics, therefore, have difficulty accessing their sight vocabulary and have to rely on sublexical procedures to recover the pronunciation of a word. However, there are a sizeable number of phonetically irregular words within the English language that cannot be accurately pronounced via the sublexical route. For

example, attempts to decode the irregular words 'pint', 'have' and 'yatch' via grapheme-phoneme correspondence rules would result in pronunciations that rhyme with 'mint', 'save' and 'patch'. Such irregular words can only be read correctly by the lexical route. The defining characteristic of surface dyslexia is, therefore, a difficulty with reading irregular words.

Castles and Coltheart (1993) proposed that these phonological and surface subtypes of acquired dyslexia also existed within the developmental dyslexic population. However, instead of representing a complete failure or break within a particular pathway caused by brain injury, Castles and Coltheart (1993) proposed that these developmental subtypes resulted from either arrested development or inefficient functioning of the respective pathways. In order to identify this arrest or inefficiency, Castles and Coltheart used relative performance on measures of non-word and irregular word reading to divide their sample of eight to fourteen year old dyslexic boys into subtypes. They concluded that "approximately one in three children [34%] who present with reading disorders can be expected to have a particular difficulty with one reading procedure in the absence of any difficulty with the other. Many more children [85%] can be expected to have difficulties with both procedures, in varying degrees of severity" (page 174).

Following the work of Castles and Coltheart (1993), the present research focuses on the identification of phonological and surface subtypes within a developmental dyslexic sample. In contrast to Castles and Coltheart, the current study is concerned with the efficacy of this subtyping procedure within an adult population. Castles and Coltheart's (1993) classification procedure was selected as it allowed the performance of the adult dyslexics to be interpreted within an appropriate theoretical framework (e.g. a fixed model of adult functioning). Furthermore, using regressed non-dyslexic data to define 'normal performance' ensured that any resulting subtypes were specific to dyslexia and not a reflection of variation that occurred within the normal population.

In addition to establishing whether such subtypes can be identified amongst adult dyslexics, the study also aimed to examine the utility of the phonological/surface dichotomy to determine whether these subtypes do indeed represent inefficient sublexical or lexical procedures. Individuals classified as phonological dyslexics on the basis of poor non-word reading should perform relatively poorly on other decoding tasks or other sound based tasks that require phonological processing. Similarly, surface dyslexics, diagnosed by poor irregular word reading, should perform relatively poorly on other measures of lexical access. Hence, once phonological and surface groups were identified, they were compared on measures of phonological processing and lexical access.

The aetiology of developmental phonological and surface dyslexia is differentially perceived within subtyping and uni-dimensional frameworks (see Chapter 1). Whereas Castles and Coltheart proposed the existence of distinct subtypes, the unitary view explains individual variation in terms of differences in the severity of a single underlying core deficit (e.g. phonological processing). In this instance, dyslexic scores are represented on an unbroken, continuous distribution differing in terms of the degree or severity of impairment. According to the unitary view performance within the dyslexic group varies from good to bad on a continuous scale with no obvious divisions or ability groupings. For example, Manis and colleagues described the findings of Rack et al (1992) whose "dyslexics varied on a continuum from low to moderately high non-word reading skill", with typical performance representing a "moderate non-word deficit" (Manis et al 1996, page163).

Consistent with the severity viewpoint, Manis et al (1996) and Stanovitch et al (1997) maintained that phonological dyslexia represented a severe and specific phonological processing deficit, whilst surface dyslexia was a milder form of phonological deficit, combined with a global delay in word recognition. Phonological dyslexia was considered to represent "true developmental deviancy" (Stanovich et al, 1997, page 123), whilst surface dyslexia was seen as a developmental delay or lag (see also Snowling and Nation, 1997). Stanovich et al (1997) argued that in addition to mild phonological deficits, surface dyslexics lacked the "word-specific knowledge" (page 124) normally acquired through exposure to

print. Since insufficient word knowledge has been implicated as indicative of surface dyslexia, the current study included measures of word knowledge and word recognition in order to contrast the abilities of adult phonological and surface subgroups.

3.2.2 Design

The analysis reported in this section included an initial classification procedure in which the adult developmental dyslexics were placed into surface or phonological subgroups based on the procedures of Castles and Coltheart (1993). This was followed by an assessment of the utility of this classification process that involved assessing the identified subgroups on measures of phonological and orthographic processing. Further investigations of potential differences between subgroups in terms of word recognition and word knowledge were also performed to assess the alternative accounts of phonological and surface dyslexia proposed by Stanovich and others (see previous section). The following measures were, therefore, incorporated in this analysis.

Castles and Coltheart's (1993) Task: Castles and Coltheart used relative performance on measures of non-word and irregular word reading to divide their sample of eleven year old dyslexic boys into subtypes. The present study included the Castles and Coltheart's (1993) Single Word Reading Task to allow the same classification procedure to be undertaken with the current sample of adult dyslexics. This task incorporated lists of phonetically regular and phonetically irregular words and a list of relatively simple non-words (e.g. gop, phot, gurdet). The number of items pronounced correctly represented the subject's accuracy score out of a maximum of 30 for each list. The time taken to read each list was also recorded to estimate efficiency of processing. This latter measure was deemed important given the potential for single-word reading accuracy measures to be less discriminating amongst an adult population (see above introduction).

Phonological Processing: The measures of phonological awareness included were the spoonerisms and alliteration and rhyme fluency subtests from the Phonological

Assessment Battery (Frederickson, 1995) and the bespoke complex non-word reading task derived from the research literature.

The spoonerisms task required the manipulation of initial sounds within and between words (eg, replace the first sound of a word with a given sound, 'fun' with a 'b' = 'bun', or with the first sound of a second word, 'bull' with 'fed' = 'full', or the transposition of initial sounds across two words, 'fed' and 'man' = 'med fan'). Such phonological manipulation tasks have been found to cause difficulties for individuals with dyslexia, with latency scores being particularly slow amongst adult dyslexics (see above introduction). The present study, therefore, noted the time taken to complete the tasks as well as the number of errors made.

The fluency tasks assessed the subject's ability to use phonological codes to retrieve information from long term memory. Alliteration and rhyme conditions required individuals to retrieve words that started with, or ended in, particular sounds. Together they provide an indication of the individual's ability to use phonological units of varying size (e.g. single phonemes or rime units that comprise several phonemes) and position within words. These tasks should also provide an indication of the size of the individual's phonological lexicon. Again, such fluency tasks have been found to differentiate those with a phonological deficit from those without (see Frederickson, Frith and Reason, 1996).

The decoding (non-word reading) task required participants to read an additional list of non-words, separate from the Castles and Coltheart (1993) items that were used to classify the groups. These non-words were specifically selected to be linguistically more complicated than those used by Castles and Coltheart (see Measures and Procedures section above). Correct decoding of these words was only possible via some level of grapheme to phoneme conversion and, therefore, this test provided an independent measure of the individual's ability to translate a written symbol into its corresponding phonological form. Such skills have been found to be difficult for individuals with dyslexia, though there is disagreement about whether simple non-words are effective at discriminating variability amongst readers of differing ability (see Rack et al, 1992).

Lexical Access: The measures of lexical access included in the study were the rapid naming subtests from the Phonological Assessment Battery (Frederickson, 1995) and an adaptation of Olson et al's (1985) Orthographic Choice Task.

The rapid naming tasks involved the speeded retrieval of information from long term memory. These measures consisted of a picture naming condition and a digit naming condition. In both instances the subject was required to name a random sequence of 50 stimuli as quickly as possible. The stimuli were commonly used and familiar items: five common objects and the digits one through nine (excluding seven). This task assessed the subject's ability to access a familiar phonological code from memory and is therefore analogous to lexical retrieval.

The Orthographic Choice Task was designed to assess word access that could not be successfully achieved via grapheme-phoneme translation processes. The task of distinguishing between correctly spelt words (goat) and pseudohomophones (gote) meant that phonological strategies would lead to indistinguishable outputs and poor performance on the task. The use of phonological processes would not aid selection as the words within each pair produced the same pronunciation when sounded out. Therefore, only knowledge of orthographic codes could be used to select the correct response. Subjects were instructed to complete the task as quickly, but as accurately as possible allowing measures of accuracy and speed to be noted.

Word Knowledge and Word Recognition: The measures of word knowledge and word recognition included in the analysis were the semantic condition from the verbal fluency subtest of the Phonological Assessment Battery (Frederickson, 1995), the vocabulary subtest from the Wechsler Adult Intelligence Scale-Revised (WAIS--R: Wechsler, 1981) and the single word reading test from the Wide Range Achievement Test (WRAT: Jastak and Wilkinson, 1993).

The semantic fluency task required subjects to name as many foods and animals as possible. The average number of items generated in 30 seconds was recorded. This aspect of fluency assessed the subject's ability to locate and retrieve semantic codes

189

from long term memory and, therefore, provides an indication of the size of the individual's mental lexicon independent of phonological processing.

The vocabulary test required subjects to define words by providing synonyms, major uses, primary features or general classifications. Each word was presented verbally by the tester, with a printed version remaining available to the subject at all times. Responses were scored either zero, one or two based on the marking criteria reported in the test manual, and the test was discontinued following five consecutive scores of zero. The raw score was converted into an age appropriate scaled score with a mean of ten and a standard deviation of three. This task provided an indication of the individual's word knowledge and general verbal ability.

WRAT single word reading required subjects to read 42 words of increasing complexity, with the number of words pronounced correctly representing the score for this measure (an additional 15 points were available for letter reading, following the procedures for the test). The test was discontinued after 10 incorrect responses and/or omissions. This task was used to provide an indication of the individual's ability to recognise written words of varying frequency (e.g. relatively common to unfamiliar). Although potentially harder for those with literacy related difficulties, this task provides an index of familiarity with the written word for the dyslexic sample as whole and, between any identified subtypes.

3.2.3 Results

3.2.3.1 Subject Categorisation

The standard procedure devised by Castles and Coltheart (1993) was adopted to divide the sample of dyslexic adults into phonological and surface subtypes. This involved assessing the relative performance of subjects on Castles and Coltheart's irregular word and non-word reading tasks.

In order to establish which individuals within the dyslexic sample could be classified as phonological dyslexics, the number of irregular words read correctly by the non-dyslexics was used to predict non-word accuracy. Upper and lower confidence limits

were determined beyond which only 10% of the non-dyslexic scores would be expected to fall. The dyslexics' scores were then imposed on the graph, with those falling below the lower 10% confidence interval being classified as phonological dyslexics; ie, individuals whose non-word reading accuracy was substantially lower than that predicted on the basis of irregular word reading.

The same procedure was adopted to identify surface dyslexics, with non-word reading being used to predict irregular word reading. Those dyslexics falling beyond the lower 10% confidence interval were achieving levels of irregular word reading accuracy below that predicted on the basis of non-word reading and were categorised as surface dyslexics (Appendix E presents graphical and procedural information for this categorisation process).

Following initial analyses of variance (anova) to determine any effects of subtype on each measure, subsequent analyses focused on two comparisons: the first comparing each of the dyslexic groups against the non-dyslexic group, the second specifically contrasting surface and phonological subtypes. Anovas comprised a single independent factor with four levels (phonological, surface and unclassified dyslexics, and non-dyslexics). Follow-up analyses incorporated the 'least significant difference' (LSD) procedure to increase the possibility of identifying any differences between the groups. Comparable analyses of covariance were also performed controlling for age differences. The latter are only reported when their findings differ from those of the anova and LSD analyses.

Preliminary analyses indicated differences between the four groups on all of the Castles and Coltheart reading tasks (see Table 3.7). Contrasts revealed that the non-dyslexics outperformed the phonological dyslexics on all accuracy tasks and non-word reading speed (all p<0.05). The non-dyslexics did not differ statistically from the phonological dyslexics on regular word reading speed (p=0.258) or irregular word reading speed (p=0.231). The non-dyslexics outperformed the surface dyslexics on all tasks (all p<0.001). Comparisons between the non-dyslexics and the unclassified group revealed statistical differences on all tasks (all p<0.05) except for regular word reading accuracy (p=0.067 and p=0.139 when controlling for age) and

191

irregular word reading speed when controlling for age (p=0.090). Contrasts between phonological and surface dyslexics revealed that the phonological dyslexics significantly outperformed the surface dyslexics on all tasks with the exception of non-word reading accuracy, where the performance of the surface dyslexics was superior (see Table 3.7). When controlling for age the significance of the difference between the phonological and surface dyslexics on regular word reading accuracy was reduced (p=0.058).

Table 3.7: Regular, irregular and non-word reading accuracy and speed scores for the non-dyslexics and the three dyslexic subgroups identified using Castles and Coltheart's standard procedure. Average score (with standard deviations in brackets), the effects of subtype and post hoc contrasts between phonological and surface dyslexics displayed.

	Phonological N=14	Surface N=14	Unclassified N=15	Non-Dyslexic N=28	F (df=70)	Post Hoc Phon / Sur
Regular word accuracy (number correct out of 30)	28.71 (1.77)	27.29 (3.15)	28.93 (1.03)	29.93 (0.26)	7.947 (p<0.001)	p=0.027
Regular word speed (time in seconds)	16.96 (5.86)	35.71 (23.96)	20.87 (9.46)	12.57 (2.04)	12.369 (p<0.001)	p<0.001
Irregular word accuracy (number correct out of 30)	25.36 (1.50)	18.79 (5.04)	25.13 (3.40)	28.32 (1.54)	32.397 (p<0.001)	p<0.001
Irregular word speed (time in seconds)	23.07 (8.81)	55.43 (34.83)	27.40 (11.93)	16.39 (3.61)	17.101 (p<0.001)	p<0.001
Non-word accuracy (number correct out of 30)	15.43 (3.98)	21.50 (5.21)	21.53 (6.76)	27.32 (2.86)	21.695 (p<0.001)	p=0.001
Non-word speed (time in seconds)	41.64 (21.67)	66.29 (43.79)	43.20 (16.17)	20.89 (5.18)	12.584 (p<0.001)	p=0.006

The classification procedure of Castles and Coltheart requires that the non-dyslexics' scores be used to estimate intervals within which the majority of readers would perform. As would be expected, these adult able readers produced ceiling effects on the accuracy measures of all three tasks, reducing the variance on which confidence intervals are calculated. Based on this, and the recommendations of Snowling, Bryant and Hulme (1996), the current study repeated the classification procedure substituting reading speed for reading accuracy (see Appendix E for graphical and procedural information on the categorisation process). The rationale for this modification of Castles and Coltheart's standard criteria was based on the view that speed provides a measure of the efficiency of the respective reading processes (Snowling, Bryant and Hulme, 1996). If phonological and surface dyslexia result from the inefficient functioning of sublexical and lexical procedures, such inefficiency would be evident in the relative speed of processing of the two pathways. Therefore, reading speed should be as appropriate a measure of functioning as reading accuracy. Furthermore, response time is particularly useful when contrasting the performance of adult dyslexics with adult non-dyslexics (Wolf and O'Brien, 2001).

Analyses indicated differences between the groups formed by this efficiency procedure on each of the Castles and Coltheart reading tasks (see Table 3.8). Contrasts revealed that the non-dyslexics outperformed the phonological and surface dyslexics on all tasks (all p<0.05), but only differed statistically from the unclassified group on the measure of non-word reading accuracy (p<0.05). A difference between the non-dyslexics and the unclassified group was identified on irregular word reading (p=0.048); however, this became non-significant when age was controlled for (p=0.127). Comparisons of phonological and surface dyslexics revealed no evidence of differences between the groups on regular word reading accuracy nor non-word reading accuracy or speed. However, the phonological dyslexics outperformed the surface dyslexics on measures of regular word reading speed and irregular word reading accuracy and speed (see Table 3.8).

Table 3:8. Regular, irregular and non-word reading accuracy and speed scores for the non-dyslexics and the three dyslexic subgroups identified by the efficiency criteria. Average score (with standard deviations in brackets), the effects of subtype and post hoc contrasts between phonological and surface dyslexics displayed.

	Phonological N=24	Surface N=9	Unclassified N=10	Non-Dyslexic N=28	F (df=70)	Post Hoc Phon / Sur
Regular word accuracy (number correct out of 30)	28.00 (2.54)	27.78 (2.11)	29.60 (0.52)	29.93 (0.26)	7.737 (p<0.001)	p=0.735
Regular word speed (time in seconds)	23.63 (18.01)	37.22 (15.54)	14.85 (3.67)	12.57 (2.04)	11.116 (p<0.001)	p=0.005
Irregular word accuracy (number correct out of 30)	23.46 (4.28)	19.33 (5.66)	25.80 (1.93)	28.32 (1.54)	18.973 (p<0.001)	p=0.003
Irregular word speed (time in seconds)	30.79 (20.91)	61.67 (31.78)	21.60 (8.92)	16.39 (3.61)	16.936 (p<0.001)	p<0.001
Non-word accuracy (number correct out of 30)	17.79 (5.82)	21.00 (5.27)	22.40 (6.45)	27.32 (2.86)	16.843 (p<0.001)	p=0.097
Non-word speed (time in seconds)	54.42 (32.01)	62.67 (32.51)	28.90 (13.72)	20.89 (5.18)	13.577 (p<0.001)	p=0.355

195

The standard regression procedure led to 65% of the adult dyslexic sample being divided into subtypes. These consisted of an equal number of phonological and surface dyslexics (32.5% in both cases). The efficiency criteria resulted in 77% of the sample being divided into subtypes. Of these, 56% were determined to be phonological dyslexics and 21% surface dyslexics. Table 3.9 compares these findings to those of Castles and Coltheart (1993).

Table 3.9: Comparison of the findings of Castles and Coltheart (1993) with the current study.

	Castles & Coltheart (1993)	Standard Criteria	Efficiency Criteria
Number of non-dyslexics	56	28	28
Number of dyslexics	53	43	43
Mean age (years:months)	11:2	24:4	24:4
Number of phonological subtype	29 (55%)	14 (32.5%)	24 (56%)
Number of surface subtype	16 (30%)	14 (32.5%)	9 (21%)
Number unclassified	8 (15%)	15 (35%)	10 (23%)

On the basis of these findings it does appear possible to divide a sample of adult dyslexics into subtypes.

3.2.3.2 Utility of procedures

Having identified these subtypes in an adult population the next step was to examine their utility. The non-dyslexics and the three dyslexic groups were compared on the additional tasks of phonological processing, lexical access, word knowledge (vocabulary and semantic fluency) and word recognition. Table 3.10 presents

summary data for the subgroups identified by the standard procedure and Table 3.11 for the efficiency determined subgroups.

For each of the phonological processing measures on which the groups were compared (ie, the spoonerisms task, complex non-word reading task and alliteration and rhyme fluency tasks), initial analysis indicated differences between the groups with regard to the number of correct responses and time taken to complete the task. Contrasts between the groups showed that the non-dyslexics outperformed all the dyslexic subgroups (all $p<0.05$) except the unclassified group determined by the efficiency criteria on alliteration fluency ($p=0.069$).

However, no statistical differences between phonological and surface subtypes were identified. These results were consistent across the two classification procedures. That is, irrespective of whether the subgroups were determined by the standard or efficiency criteria, in general the non-dyslexics outperformed the dyslexics and no differences between phonological and surface subtypes on any of the phonological tasks were identified.

As with the phonological tasks, differences between the groups were apparent on the measures of lexical access. Contrasts indicated that the performance of the non-dyslexics was superior to that of the dyslexics on both rapid naming tasks (all $p<0.05$) accept for the unclassified group determined by the efficiency criteria on digit naming ($p=0.054$ and $p=0.088$ when controlling for age). The surface dyslexics were found to take significantly longer to complete the picture naming task than the phonological dyslexics. This was the case for both standard ($p=0.058$ and $p=0.045$ when controlling for age) and efficiency defined groups ($p=0.042$ and $p=0.022$ when controlling for age). No difference between phonological and surface subtypes was found on the digit naming task for either standard or efficiency defined groups.

Analyses of the orthographic choice task indicate that results varied as a function of classification procedure. When the standard procedure was used to classify the groups, contrasts revealed that, for accuracy, the non-dyslexics significantly outperformed the phonological and surface dyslexics ($p<0.05$) but not the

197

unclassified group (p=0.080). With regard to speed, the non-dyslexics outperformed the surface and unclassified dyslexics (p≤0.05) but not the phonological dyslexics (p=0.299). The performance of the surface dyslexics was significantly poorer than that of the phonological dyslexics for both accuracy and speed measures (see Table 3.10). When the subgroups were determined by the efficiency criteria, contrasts revealed that for both accuracy and speed the non-dyslexics significantly out-performed the phonological and surface dyslexics (all p<0.05) but not the unclassified group (p=0.131 for accuracy, p=0.486 for speed). The performance of the surface dyslexics was significantly poorer than that of the phonological dyslexics in terms of accuracy but not speed (see Table 3.11).

Measures of word knowledge and word recognition also presented evidence of an effect of group. Again, the non-dyslexics outperformed all of the dyslexic groups (p< 0.01 in all cases), irrespective of the classification procedure. When the dyslexic subgroups were determined by the standard procedure, contrasts revealed that the phonological dyslexics significantly outperformed the surface dyslexics on the vocabulary and single word reading tasks, with the difference on the semantic fluency task approaching significance (p=0.042 when controlling for age) (see Table 3.10). However, phonological and surface subtypes classified by the efficiency criteria did not differ statistically on any of these measures (see Table 3.11).

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Table 3.10: Means (with standard deviations in brackets) for each of the classification-independent variables on which the non-dyslexics and standard dyslexic subgroups were compared.

	Phonological N=14	Surface N=14	Unclassified N=15	Non-dyslexic N=28	F (df=70)	Post Hoc Phon / Sur
Spoonerisms accuracy	26.00 (7.43)	27.36 (10.58)	28.93 (9.08)	35.93 (3.63)	7.743 (p<0.001)	p=0.630
Spoonerisms speed	314.07 (161.73)	309.07 (139.69)	296.87 (127.42)	139.71 (40.28)	12.233 (p<0.001)	p=0.908
Complex non-word reading task	14.93 (3.65)	16.21 (4.79)	17.87 (4.16)	22.11 (2.51)	15.689 (p<0.001)	p=0.352
Alliteration fluency	9.39 (2.73)	7.96 (1.99)	7.10 (2.16)	11.34 (3.12)	9.998 (p<0.001)	p=0.161
Rhyme fluency	6.64 (3.51)	5.89 (1.56)	6.87 (2.20)	9.45 (2.78)	7.504 (p<0.001)	p=0.460
Rapid naming of pictures	34.29 (4.25)	38.89 (7.08)	42.00 (10.40)	29.38 (3.19)	15.349 (p<0.001)	p=0.058
Rapid naming of digits	20.96 (4.34)	23.54 (6.55)	24.09 (7.85)	14.88 (3.28)	13.359 (p<0.001)	p=0.212
OCT accuracy	48.57 (2.62)	41.57 (8.80)	49.40 (2.29)	51.79 (0.42)	18.725 (p<0.001)	p<0.001
OCT speed	70.21 (22.04)	155.43 (120.74)	86.53 (29.10)	51.04 (9.00)	11.124 (p<0.001)	p<0.001
Vocabulary	11.43 (1.65)	9.86 (1.88)	11.33 (1.29)	13.75 (1.88)	18.032 (p<0.001)	p=0.019
Semantic fluency	16.32 (3.79)	13.50 (3.38)	15.27 (3.17)	20.44 (4.45)	12.215 (p<0.001)	p=0.059
Single word reading	44.07 (2.87)	39.29 (5.59)	43.67 (3.99)	50.86 (2.97)	32.537 (p<0.001)	p=0.001

199

Table 3.11: Means (with standard deviations in brackets) for each of the classification-independent variables on which the non-dyslexics and efficiency defined dyslexic subgroups were compared.

	Phonological N=24	Surface N=9	Unclassified N=10	Non-dyslexic N=28	F (df=70)	Post Hoc Phon / Sur
Spoonerisms accuracy	26.13 (10.20)	28.11 (6.53)	30.10 (7.75)	35.93 (3.63)	8.188 ($p<0.001$)	$p=0.492$
Spoonerisms speed	330.17 (156.05)	316.00 (122.45)	240.90 (97.74)	139.71 (40.28)	14.580 ($p<0.001$)	$p=0.743$
Complex non-word reading task	15.54 (4.39)	15.89 (4.37)	18.80 (3.36)	22.11 (2.51)	16.326 ($p<0.001$)	$p=0.806$
Alliteration fluency	7.77 (2.48)	7.56 (1.79)	9.50 (2.59)	11.34 (3.12)	9.089 ($p<0.001$)	$p=0.839$
Rhyme fluency	6.64 (2.92)	6.28 (1.62)	6.25 (2.31)	9.45 (2.78)	7.133 ($p<0.001$)	$p=0.727$
Rapid naming of pictures	37.98 (6.87)	43.22 (12.30)	35.40 (5.14)	29.38 (3.19)	13.588 ($p<0.001$)	$p=0.042$
Rapid naming of digits	23.38 (6.16)	26.43 (7.02)	18.55 (4.36)	14.88 (3.28)	18.059 ($p<0.001$)	$p=0.128$
OCT accuracy	47.29 (5.68)	41.78 (8.79)	49.20 (2.35)	51.79 (0.42)	11.819 ($p<0.001$)	$p=0.003$
OCT speed	106.75 (91.96)	136.56 (74.97)	66.60 (15.22)	51.04 (9.00)	6.473 ($p<0.001$)	$p=0.211$
Vocabulary	10.83 (1.90)	10.67 (1.41)	11.20 (1.69)	13.75 (1.88)	14.282 ($p<0.001$)	$p=0.815$
Semantic fluency	15.19 (3.86)	13.94 (3.88)	15.65 (2.47)	20.44 (4.45)	10.838 ($p<0.001$)	$p=0.425$
Single word reading	42.54 (4.66)	39.89 (5.28)	44.20 (3.71)	50.86 (2.97)	27.003 ($p<0.001$)	$p=0.096$

200

3.2.4 Discussion

On the basis of the current findings it does appear possible to divide a sample of adult dyslexics into phonological and surface subtypes. In this respect, the findings seem consistent with Castles and Coltheart. However, the extent to which these subtypes represent the inefficient functioning of sub-lexical or lexical procedures is unclear. Of particular concern are the findings related to the assessment of phonological skills. On four independent sound-based measures, the phonological dyslexics were not significantly disadvantaged relative to the surface dyslexics. These results were consistent irrespective of whether the groups were classified according to Castles and Coltheart's standard procedure or whether an efficiency criteria was employed. The lack of a difference between phonological and surface subtypes on the complex non-word reading measure was particularly relevant, as it was on the basis of relatively poor non-word reading that the phonological dyslexic group were initially classified and distinguished from the other groups. With regard to the additional measures of lexical access, the pattern of results was more equivocal. On the task that required the rapid naming of pictures the phonological dyslexics significantly outperformed the surface dyslexics. The performance of the surface dyslexics on the orthographic choice task was also weaker than that of the other groups in terms of both accuracy and speed.

Comparisons of phonological and surface dyslexics on measures of phonological processing and lexical access remained generally consistent across the standard and efficiency classification systems. However, the method used to identify the groups exerted a considerable effect on comparisons of word knowledge and word recognition. When the groups were defined by the standard procedure the phonological dyslexics outperformed the surface dyslexics on measures of word knowledge and word recognition. When the efficiency criteria was used, no difference between the groups were identified.

An alternative interpretation of the phonological / surface dichotomy (Manis et al, 1996) proposes that such subtypes result from different causal factors. Phonological dyslexia is seen to represent a severe and specific phonological processing deficit, whilst the surface dyslexic profile is believed to result from a global delay in word

recognition. Surface dyslexics are described as being generally impaired in component word reading skills (both phonological and orthographic) and their reading behaviour is likened to that of younger non-dyslexics of the same reading age. This hypothesis that phonological and surface dyslexia follow differential developmental sequences is expanded upon by Stanovich et al (1997) who refer to phonological dyslexia as a developmental deviancy, caused by relatively severe deficits in phonological processing, and surface dyslexia as a developmental delay based on a milder form of phonological deficit and a lack of reading experience. Stanovich et al hypothesised that exposure to print contributed to the development of orthographic processing mechanisms and consequently the ability to read irregular words.

In accordance with the findings of these authors, we would expect to identify differences between surface and phonological dyslexics on measures of phonological processing. Specifically, we would expect the performance of the phonological dyslexics to be poorer than that of the surface dyslexics. However, irrespective of classification procedure, no differences were identified between the phonological and surface dyslexics on the measures of phonological processing. Although both subtypes were underachieving relative to the non-dyslexics, the performance of the phonological dyslexics was not significantly worse than that of the surface dyslexics. In addition to their phonological difficulties, the surface dyslexics also showed an orthographic processing deficit as evidenced by their performance on the picture naming and orthographic choice task. Comparisons of efficiency defined subgroups yielded very similar results to those of Manis et al (1996) whose phonological dyslexics also outperformed the surface dyslexics with regard to orthographic choice task accuracy but not latency.

Skinner (1981) outlined several issues pertinent to the development of classification systems. Firstly, potential subtyping systems should be derived from sound theoretical models and be subject to a continuous process of theoretical validation. The measures used to divide samples should reflect this theoretical framework and be both valid and reliable. A psychometrically appropriate subtyping system should result in the classification of the majority of individuals. Subtypes should remain

consistent across different classification procedures and samples. The continuity of subtypes and how membership is affected by age and developmental changes should also be considered. A classification system should prove reliable when evaluated against external, parallel measures independent of those used to classify the groups. Finally, the model should inform with regard to the aetiology of the different subtypes, and how best to assess and remediate the specific deficits inherent in each. Subtyping models should promote understanding through the identification of cognitive strengths and weaknesses, which can then be used to develop specific intervention strategies, tailored to the needs of each subtype. The development of reliable and valid subtypes should help establish links between causal factors, assessment procedures and ultimately response to treatment. In summary, Rispens et al (1994) maintained that "a classification system consists of generally accepted, valid descriptions of disorders, based in explicit and clearly operationalized criteria, with sufficient empirical support with respect to clinical utility and coverage". (page 71).

The phonological / surface classification system adheres to Skinner's (1981) first requirement in that it is derived from a precise theoretical model of reading. In addition, the measures used to divide the sample (to the best of our current understanding) directly reflect this theoretical framework. One of the main criticisms of Castles and Coltheart's procedure was the use of a fixed model of adult functioning as a framework in which to consider the learning to read process (Snowling, Bryant and Hulme, 1996). Since the current sample consisted of adult dyslexics, this framework is perhaps not so inappropriate.

The classification procedure, however, has difficulty meeting Skinner's (1981) additional guidelines as illustrated by Table 3.12. This table compares the proportion of phonological and surface subtypes identified by Castles and Coltheart (1993), Manis et al (1996), Stanovich et al (1997) and the current study. As detailed previously, Castles and Coltheart (1993) used 56 age-matched non-dyslexic males to divide their sample of 53 dyslexic males into subtypes. Stanovich et al (1997) extracted from Castles and Coltheart's (1993) data a subset of 40 dyslexics who were matched with 17 of the non-dyslexics for reading age. These reading-age-matched

non-dyslexics were then used to establish the regression line and confidence intervals. In addition to the re-analysis of the original Castles and Coltheart data, Stanovich et al (1997) also investigate the frequency of phonological and surface subtypes within a younger sample of dyslexics (mean age 8 years 10 months) again using both chronological (mean age 8.10) and reading age matched control groups (mean age 7.4).

Manis et al (1996) also looked at the frequency of phonological and surface subtypes identified using chronological and reading age matched controls. The mean age of the dyslexics studied by Manis et al was 12.4 and, unlike Castles and Coltheart, their sample included females as well as males (14 males and 37 females). Manis et al's chronological age controls (16 females, 35 males) had a mean age of 11.7 and the 9 females and 18 males that constituted their reading age control group (as determined by the Woodstock word identification test) had a mean age of 8.5.

Table 3.12: The percentage of phonological and surface dyslexics identified by Castles and Coltheart (1993), Manis et al, (1996), Stanovich et al (1997) and the current study.

	Subject details	Mean Age (range)	Phonological	Surface	Total	Poor at both
Castles & Coltheart (1993)*	53 Dyslexics 56 CA Non-dyslexics	11:2 (8-14)	55%	30%	85%	*5.7%
	40 Dyslexics 17 RA Non-dyslexics	11:5 8:5	38%	5%	43%	NA
Manis et al (1996)	51 Dyslexics 51 CA Non-dyslexics	12:4 (9-15) 11:7	33%	29%	62%	9.8%
	51 Dyslexics 27 RA Non-dyslexics	12.4 8:5	24%	2%	26%	0%
Stanovich et al (1997)	68 Dyslexics 44 CA Non-dyslexics	8:10	25%	22%	47%	27.9
	68 Dyslexics 23 RA Non-dyslexics	8:10 7:4	25%	1.5%	26.5%	NA
Current data Standard procedure	43 Dyslexics 28 Non-dyslexics	22:7 27:1	32.5%	32.5%	65%	11%
Current data Efficiency procedure	43 Dyslexics 28 Non-dyslexics	22:7 27:1	56%	21%	77%	0%

* The analysis of the Castles and Coltheart data in relation to a reading age control group was derived from Stanovich et al (1997), as was the figure pertaining to the percentage of subjects 'poor at both' in Castles and Coltheart's original sample.

As can be seen from Table 3.12, the majority of subjects were classified when a chronological age control group was used to define the parameters of normal performance. Far fewer were classified when reading age control groups were used. Indeed, in two cases (Manis et al and Stanovich et al's reading age defined groups) the total number of individuals classified was less than the 34% (1 in 3) predicted by Castles and Coltheart.

Table 3.12 presents information pertaining to the stability of the phonological / surface classification system across different samples and age ranges. In the absence of the current adult data Stanovich et al (1997) hypothesized that "with development, there is increasing dissociation between lexical and sublexical processes in dyslexic children" (page 117). The basis for this hypothesis was the finding that in comparison to the older samples of Castles and Coltheart and Manis et al, an increased percentage of Stanovich et al's younger dyslexics proved to be poor at both non-word and irregular word reading. The current study also identified a group of dyslexics who were relatively poor at both irregular and non-word reading. Five individuals (approximately 11%) were determined to be both phonological and surface dyslexics following classification by the standard procedure (3 were phonological dyslexics under the efficiency criteria and 2 were surface dyslexics). Although this percentage was smaller than that identified by Stanovich et al it was greater than the percentages identified by Castles and Coltheart and Manis et al. The current data therefore, does not support the trend proposed by Stanovich et al.

Within the current study, the standard procedure resulted in approximately 65% of the adult sample being classified into an equal number of phonological and surface dyslexics (32.5% in each case), with 35% remaining unclassified. Changing to an efficiency criteria, reduced the number of unclassified dyslexics (23%) and increased the number of phonological dyslexics (56%). This also led to a reduction in the number of surface dyslexics (21%), with five dyslexics classified as surface subtypes by the standard procedure being re-classified as phonological subtypes by the efficiency criteria.

There appears, therefore, to be minimal continuity across different age ranges and classification procedures (e.g. the use of chronological or reading age control groups). The current study also failed to demonstrate stability across different classification methods, with individuals shifting from one subtype to another following classification by either the standard or efficiency criteria. Finally, the current study showed that the phonological / surface classification system lacked reliability when evaluated against external, parallel measures, independent of those used to classify the groups. On no measure of phonological processing was the performance of the phonological dyslexics worse than that of the surface dyslexics.

Within the current study, a subgroup of surface dyslexics were identified who showed both phonological and orthographic processing deficits. What remains unclear is whether this pattern of reading behaviour can be explained by the dual-route model, which in this instance must infer partial damage to both lexical and sublexical routes, or whether the data supports alternative interpretations advocating a general delay in word recognition resulting from a lack of reading experience. Most of the research conducted within this area has focused on children, where the notion of delay is meaningful. If an eleven year old dyslexic is reading quantitatively and qualitatively like a nine year old non-dyslexic, it is reasonable to assume that a normal but delayed developmental sequence is in operation. However, this argument seems less plausible in the case of adults. It would be inappropriate to describe a 20 year old who is performing like a 12 year old as delayed. When would the dyslexic with a developmental delay be expected to read like an adult? Beaton et al (1997) maintained that "it is arguably more important to be able to say that the reading of dyslexics is abnormal when compared to their peers" in this instance 'normal' adults rather than reading age matched children. Since the notion of development delay seems inappropriate when considering an adult sample, whose reading skills appear to have reached a developmental ceiling, it seems more reasonable to assume that the orthographic deficits displayed by the surface dyslexics are as enduring as their phonological impairments. What has yet to be determined is whether these "core orthographic encoding deficits" (Manis and Bailey, 2001) are in any way related to inefficient lexical processes.

Dividing dyslexic samples into subtypes is one method by which researchers have endeavoured to understand the diversity of skills and deficits within the dyslexic population. Subtyping is achieved by the partitioning of variance. Different subtyping systems are distinguished by the performance measures on which the division is made and how the cut-off point that separates one subtype from another is established. The phonological / surface classification system proposed by Castles and Coltheart used the performance of a non-dyslexic control group to divide the variance within the dyslexic group on measures of non-word and irregular word reading.

Different procedures (e.g. the use of reading age control groups or the use of speed rather than accuracy scores) resulted in different cut-off points and consequently altered the constitution of the resulting subtypes. Similar findings were identified by Rispens et al (1994) who investigated the extent to which assignment to a particular subtype differed as a function of diagnostic criteria and cut-off thresholds. The authors contrasted two classification procedures that they described as different 'operationalizations' of whole word and recoding dyslexia subtypes, which are similar to phonological and surface dyslexics respectively. Altering the classification procedure or the cut-off score (e.g. threshold score on a particular task which divides the sample into subtypes) had a considerable affect on the number of children assigned to the various subtypes. Rispens et al (1994) also examined task dependency. It was assumed that proficient readers use both lexical and sublexical mechanisms interchangeably, depending on specific task demands. Phonological and surface dyslexics, however, are perceived as applying the only reading strategy that is available to them (e.g. phonological dyslexics use lexical reading mechanisms due to inefficient sublexical mechanisms) irrespective of the task. These subtypes should, therefore, remain consistent across different reading measures. Out of the 25 poor readers studied only two (one whole word and recoding reader) obtained the same classification across the seven reading tasks. Due to this instability, the authors concluded that "if only one reading task is used in a classification procedure, there is a great risk of misclassification" (page 87).

The above findings have been used to argue that partitioning variance along a continuum is subjective and arbitrary in that it represents a single, potential division on a continuous scale of performance on which there are no obvious divisions or ability groupings. Wright and Groner (1993) suggested that "dyslexics will not form clear ability/disability clusters and that those that do form are just one possible division along a continuum" (page 447). Similarly, Rispens et al (1994) maintained that there is no empirical support for dyslexia subtypes. Performance differences between subtypes are gradual rather than absolute or qualitative. Dyslexia subtypes are imposed rather than naturally occurring, conceived on the basis of various classification procedures and arbitrary thresholds.

The ultimate aim of a classification system is to provide "valid and reliably diagnostic categories – that improve the quality of clinical practice" (Rispens et al, 1994, page 72 &73). Accordingly, the final point made by Skinner (1981) concerns the extent to which a subtyping model can inform with regard to the cause of the different subtypes, and how best to assess and remediate the specific deficits inherent within each. The procedure outlined by Castles and Coltheart succeeds in reducing individual differences into distinct subtypes; however, this reduction does not appear to result in groups that differ in any meaningful way. Before subtyping systems can aid diagnosis and inform teaching, it is necessary to establish precisely what they are telling us about the individuals within in each group. The aim of the current study was to determine whether Castles and Coltheart's classification system could be used to identify phonological and surface subtypes in a sample of adult dyslexics. The findings cast doubt on the efficacy of this procedure as a practical means of explaining individual differences amongst adult dyslexics.

3.2.5 Modifications and Future Research

The current study suggests that meaningful subtypes cannot be identified amongst adult dyslexics. However, this might not have been the case had a subtyping procedure other than Castles and Coltheart's (1993) been used. Future research may wish to consider alternate subtyping procedures, such as the clinical or other statistical methods described in section 3.2.1. Error analysis of reading or spelling

errors could be used to classify dyslexics into subtypes or as a means of validating existing subtypes. For example, as an additional form of external validation Manis et al (1996) compared the irregular word reading errors made by their phonological and surface dyslexics. Compared to the surface dyslexics, the phonological dyslexics made significantly more phonologically inappropriate errors. When a similar scoring criteria (see Manis et al, 1996) was used to classify the irregular word reading errors made by the current phonological and surface dyslexics (standard and efficiency defined groups), the phonological dyslexics did not demonstrate an increased tendency to make phonologically inappropriate errors compared to the surface dyslexics.

Although future research could consider alternate subtyping procedures these may prove just as inconclusive as Castles and Coltheart's, i.e. the possibility exists that subtypes only differ on the measures which were used to identify them and are of limited theoretical or practical use.

3.3 STUDY VIc: Severity

3.3.1 Introduction

Section 3.2 endeavoured to determine if the variance within phonological and orthographic processes could be used to classify dyslexic adults into subtypes. Section 3.3 investigates the extent to which varying degrees of severity within these processes and others can explain differences in literacy skills. To this end, predictors of single word recognition, reading comprehension and spelling were investigated.

As described previously, phonological processing is fundamental to sublexical functioning. If the phonemes represented within the language processing system lack specificity, or the efficiency with which they are utilised during decoding or encoding tasks is deficient, sublexical reading and spelling processes are likely to be compromised. Although important to both reading and spelling, phonology is believed to play a greater role in spelling, with alphabetic skills initially developing to support spelling acquisition. As a consequence, phonological deficits 'should' have a greater impact on spelling ability (Treiman, 1977). Burt and Butterworth (1996) site evidence that good spellers demonstrated better phonological awareness skills than poor spellers; e.g. good spellers made more phonologically acceptable spelling errors and were better at non-word reading (Waters et al, 1985; Frith, 1980).

Phonology is deemed more important to the acquisition of literacy skills with adult/competent reading and spelling of familiar words being predominantly mediated by lexical processes. As with reading, lexical spelling mechanisms require the accessing of known letter strings from the orthographic lexicon or sight vocabulary. However, even in adult competent readers/spellers, proficient phonological skills are still required to decode/encode difficult or unfamiliar words. Pennington et al (1987) maintained that phonological processing ability continued to develop until adulthood and was a better predictor of reading and spelling than orthographic processing.

Research concerning literacy development in children has found reading and spelling to be highly correlated (Newman, Fields & Wright, 1993). In general, good readers

tend to be good spellers and dyslexia usually co-occurs with dysgraphia. Even subtypes of dyslexia and dysgraphia have been found to occur together; e.g. phonological dyslexia/dysgraphia and surface dyslexia/dysgraphia (Tainturier and Rapp, 2001). The relationship between reading and spelling could potentially reflect the finding that they share certain processing components. For example, evidence from neurological case studies, and skilled adult readers, suggests that reading and spelling are mediated by a single orthographic lexicon.

Although reading and spelling are both supported by the same repository of orthographic knowledge, this knowledge is believed to be principally acquired through reading. Burt and Fury (2000) maintain that spelling is determined by the quality with which word specific knowledge is represented in the lexicon, a factor that is believed to vary with reading skill and/or experience.

An example of how poor orthographic skills can affect spelling is provided by Frith's (1985) interpretation of the 'Type B' spelling pattern. Type B spellers are individuals who have severe and enduring spelling deficits despite what appears to be adequate reading skills. Frith (1985) suggested that this profile resulted from a developmental lag during the early orthographic stage and a continuing reliance on alphabetic strategies. Orthographic processing is believed to be applied first to reading and only used as a spelling strategy once the orthographic lexicon has been established. According to Frith (1985), Type B spellers recognise words using only 'partial visual cues'. As a consequence their orthographic representations are poorly specified, thus interfering with lexical spelling. "Frith predicts that Type B spellers will eventually become orthographic readers, but that their atypical developmental experience will continue to be evidenced in very inaccurate spelling" (Burden, 1992, page 202).

An alternative interpretation of the Type B pattern is provided by Bruck and Walters (1988). These authors maintained that the Type B profile resulted from a phonological processing deficit and subsequent arrested development during the alphabetic phase. According to this interpretation, the Type B profile is analogous to dyslexia. Burden (1992) found that Type B spellers were less efficient decoders, slower readers and their performance on measures of reading comprehension and

vocabulary were weak compared to good readers/good spellers. In this instance, a phonological processing deficit interfered with both reading and spelling, although the Type B spellers were able to improve and/or compensate for their reading accuracy.

Irrespective of these differences (e.g. Frith,1985, implicating orthography and Bruck and Waters,1988, phonology), the Type B speller describes individuals with adequate single word recognition skills but enduring spelling deficits, a pattern that is common among adult dyslexics. For example, McNaughton, Hughes & Clark (1994) reviewed the findings of Gerber and Hall (1987), Gettinger et al (1982) and Hoffman et al (1987), concluding that spelling deficits where more severe and difficult to remediate than reading difficulties and the most regularly reported problem of adults with dyslexia. Spelling difficulties represent a considerable source of anxiety for dyslexic adults (more so than reading) as they are perceived to "inhibit their employment opportunities" (Leuenberger & Morris, 1990, page 103).

In addition to spelling difficulties, adult dyslexics frequently report difficulties reading for meaning, the understanding of text only gained through extensive re-reading (National Working Party's Report on Dyslexia in Higher Education, 1999). The ability to quickly comprehend lengthy and complex text represents a fundamental skill required by most higher education courses, placing dyslexics at a considerable disadvantage relative to their peers. Reading comprehension involves the extraction of meaning from text. It is an integrative process, requiring both the recognition of individual words and knowledge of their meaning. Gough and Tunmer's (1986) 'Simple View of Reading' maintained that successful reading comprehension was predominantly dependent on the speed and accuracy with which words were decoded, together with the ability to comprehend language. The model asserted that an equal amount of proficiency in both component skills was required for text comprehension. However, in a cross-validation study of this model, Chen and Vellutino (1997) found that the relationship between language comprehension and reading comprehension was mediated by reading ability. Language comprehension only facilitated reading comprehension once word recognition skills had reached a certain level of proficiency. Consequently, if reading skills were poor,

the contribution of language comprehension to reading comprehension would be minimal.

The significance of word recognition to reading comprehension is well established. Perfetti's (1985) 'Verbal Efficiency Hypothesis' maintained that word recognition accuracy and speed were fundamental to reading comprehension, with inefficient or slow word recognition mechanisms restricting the flow of information to higher levels of processing. Similarly, Kitz & Nash (1992) found that individual differences in word reading and passage reading rate predicted a considerable percentage of the variance in reading comprehension. This relationship was considered a reflection of decoding accuracy, which facilitated automatic word recognition and consequently reading speed. They went on to conclude in accordance with Perfetti, that "higher level reading skills are built upon basic decoding and phonemic awareness skills" (page 20). Such models would predict that inefficient phonological analysis, with regard to the accuracy and the speed with which phonological representations are accessed, creates a bottleneck that constricts information flow to higher levels of processing (e.g. language comprehension), consequently interfering with the extraction of meaning from text. According to these models, phonological awareness and decoding skills represent a major determinant of individual differences in reading comprehension. However, the extent to which reading comprehension is mediated by phonological processes is subject to considerable debate (see Coltheart and Coltheart, 1997, for a review). As described previously, lexical or orthographic processes represent an additional means of recognising / pronouncing words. Hence, both orthographic and phonological processes may be independently involved in the processing of individual words and consequently the ability to comprehend text.

In addition to word recognition, the development of proficient text comprehension is influenced by an individual's general language skills, to the extent that reading comprehension has been described as an "excellent measure of general verbal ability" (see Stanovich and Cunningham, 1992, page 58). The comprehension process is extremely broad, and utilises a wide range of verbal abilities. Proficient verbal semantic skills aid reading comprehension, in that they facilitate the acquisition of word knowledge, efficient metacognitive strategies (i.e. an individual's

ability to monitor and correct/alter their own performance) and the ability to draw inferences from text. Such verbal-semantic skills or verbal IQ have also been found to predict reading and spelling ability in children. For example, Newman, Fields & Wright (1993) found that general verbal ability predicted reading and spelling at age 13. In addition, a relationship between spelling and vocabulary (often used as an index of verbal IQ) has been identified in non-dyslexic adults (Burt and Fury, 2000; Stanovitch and Cunningham, 1992). Finally, Burt and Butterworth (1996) found that good spellers had greater knowledge of vocabulary than poor spellers.

In addition to word recognition skills and verbal ability, working memory has also been identified as an important component of the reading comprehension process. For example, the ability to parse a sentence relies on the temporary storage and concurrent processing of information in working memory. Since Baddeley (1986), working memory has been perceived as a limited capacity, tripartite system consisting of a central executive or processor, and two storage systems, the articulatory loop and the visual spatial sketch pad. Swanson (1999) identified unique variance in reading comprehension associated with executive processing. According to Swanson, the central executive both co-ordinates and supports processes within the language system, hence its influence on reading comprehension is two fold. Firstly, deficits in the co-ordinating functions of the central executive would be detrimental to reading comprehension, as it is a task which requires the integration of information from phonological, lexical and semantic processes. Single-word reading would be less vulnerable as it is perceived to be a more automatised process. Deficient central executive processing could therefore account for the relative ability differences between single-word reading and reading comprehension observed in some adult dyslexics. Secondly, an inefficient central executive would fail to compensate for deficient lower-level processes, for example a phonological deficit. Inefficient word identification would place an additional burden on memory, utilizing the limited resources that would otherwise be available to aid comprehension. Based on a review of the literature, Swanson (1999) used span tasks from several different domains (sentence, visual-spatial and counting) to represent central executive processing. All of these measures in isolation correlated with reading comprehension.

Daneman and Tardif (1987) also used a number of span tasks to assess the relationship between working memory processes in verbal, mathematical and spatial domains and performance on a reading comprehension task. From their investigation, they concluded that it is processing efficiency and not storage capacity that determines individual differences in reading comprehension. Furthermore, these findings were domain specific, only verbal or symbolic information correlating with reading comprehension. Daneman and Tardif went on to posit the existence of two separate processors (one for visual and one for verbal information) rather than a single central executive. In contrast, Swanson and Alexander (1997) identified a general working memory resource system, referred to as 'g', that predicted a significant amount of the variance in reading comprehension in both learning disabled and control children. 'G' was believed to be involved with the "dynamic processing of information related to the manipulation of symbols and holding of current information in thought" (page 152). Whether the domain be general (Swanson, 1999) or specific (Daneman and Tardif, 1987), it appears to be the ability to processes symbolic information efficiently rather than storage capacity that contributes to individual differences in reading comprehension.

3.3.2 Design

Word recognition, spelling and reading comprehension are complex procedures that necessitate the integration of numerous cognitive processes. The present analysis endeavoured to gain an understanding of these multifaceted operations, by isolating the basic processes that best predicted them. In doing so, it also sort to determine if differential mechanisms supported the word recognition, reading comprehension and spelling ability of dyslexic and non-dyslexic adults. A cognitive correlates approach was adopted to measure the extent to which individual differences in various cognitive processes predicted individual differences in word recognition, spelling and reading comprehension.

Three analyses were conducted in which single word reading, spelling and reading comprehension represented the dependent variables. In order to afford consistency, in each analysis, the independent variables were the same, the only difference

concerning single word reading, which represented the dependent variable in section 3.3.3.1 and an independent variable in sections 3.3.3.2 and 3.3.3.3.

In accordance with Section 3.2, measures of phonological and orthographic processing were used to provide an indication of sublexical and lexical functioning. The Spoonerisms task was used to assess phonological processing and the complex non-word reading task measured decoding ability (the ability to relate orthography to phonology within an alphabetic writing system). The OCT was used to access orthographic processing, as it required subjects to retrieve visual orthographic codes from the orthographic lexicon. A measure of vocabulary was used to provide an indication of verbal IQ and digit symbol was included as an index of processing speed. The inclusion of digit symbol was of specific pertinence to reading comprehension as it embodied a number of the functions attributed to Swanson and Alexander's (1997) 'g', namely the ability to identify, memorise and make random associations between symbols at speed.

Pearson Product Moment correlations were performed in order to identify any relationships between the dependent variables of single word recognition, spelling and reading comprehension and the predictor variables (phonological and orthographic processing, single word reading [sections 3.3.3.2 and 3.3.3.3], decoding, vocabulary and processing speed). Dyslexic and non-dyslexic groups were analysed separately.

In order to determine which of the predictor variables accounted for the most variance in the dependent variables, regression analyses were also performed. Using the Enter Method, the predictor variables were entered into the analysis following the control variables of age, sex and non-verbal IQ (Block Design, Picture Completion). For sections 3.3.3.2 and 3.3.3.3 only, the first predictor variable entered into the analysis assessed word recognition (word recognition represented the dependent variable section 3.3.3.1). Word recognition was followed by vocabulary, spoonerisms accuracy and speed, the complex non-word reading task, the orthographic choice task, and finally digit symbol. The order in which the predictor variables were entered into the analysis was then varied in order to determine the

relative contribution of the individual predictors to the dependent variables. Again dyslexic and non-dyslexic groups were analysed separately. R^2 and Adjusted R^2 values for the non-dyslexics need to be treated with caution due to the small number of subjects entered into the analyses.

3.3.3 Analysis

3.3.3.1 Word Recognition (Single Word Reading)

The current analysis investigated the extent to which phonological and orthographic processing, decoding, vocabulary and processing speed predicted individual differences in reading ability.

Pearson Product Moment correlations were performed in order to identify any relationship between the dependent (reading) and independent variables. Dyslexic and non-dyslexic groups were analysed separately. Correlations are shown in Tables 3.13.

Table 3.13: Correlations between reading and the predictor variables for the dyslexic and non-dyslexic sample.

	Single Word Reading	
	Dyslexics	**Non-dyslexics**
Vocabulary	0.732**	0.685**
Complex Non-word Reading	0.732**	0.390*
Spoonerisms Accuracy	0.527**	0.584**
Spoonerisms Speed	-0.574**	-0.331
OCT Accuracy	0.614**	0.303
OCT Speed	-0.473**	-0.175
Digit Symbol	0.335*	-0.102

** Correlation significant at the 0.01 level
* Correlation significant at the 0.05 level

The word recognition ability of the dyslexics was found to be highly correlated with measures of vocabulary, decoding, phonological and orthographic processing and less correlated with the measure of processing speed. The word recognition ability of the non-dyslexics was found to be highly correlated with vocabulary and spoonerisms accuracy, less correlated with non-word reading and not significantly correlated with spoonerisms speed, the OCT (accuracy and speed) or digit symbol.

In order to determine which of the predictor variables accounted for the most variance in word recognition, regression analyses were carried out. Predictor variables were entered into the analysis following the control variables of age, sex and non-verbal IQ (Block Design, Picture Completion). Vocabulary was the first predictor variable entered into the analysis followed by non-word reading, spoonerisms accuracy and speed, the orthographic choice task, and finally digit

symbol. Dyslexic and non-dyslexic groups were analysed separately (see Table 3.14 and Table 3.15).

Table 3.14: Variance in single word reading predicted by the independent variables for the dyslexic group. R^2 and adjusted R^2 values with significance levels and percentage increases in variance are displayed.

Predictor Variables	Single Word Reading Dyslexics N=43 (24 males & 19 females)			
	R^2	Adjusted R^2	Sig. Level	% inc. Adjusted R^2
Age & Sex	0.071	0.025	p=0.229	3%
+ Block Design & Picture Completion	0.182	0.096	p=0.098	7%
+ Vocabulary	0.687	0.645	p<0.001	55%
+ Complex Non-word Reading	0.833	0.806	p<0.001	16%
+ Spoonerisms Accuracy & Speed	0.839	0.801	p<0.001	0%
+ OCT Accuracy & Speed	0.867	0.825	p<0.001	3%
+ Digit Symbol	0.867	0.820	p<0.001	0%

For the dyslexics, the control variables of age, sex and non-verbal IQ accounted for approximately 10% of the variance in word recognition. When entered after the control variables, vocabulary predicted an additional 55% of the variability in reading. The subsequent inclusion of non-word reading increased the amount of variance predicted by 16%. Phonological and orthographic processing and processing speed predicted only minimal additional variance.

When spoonerisms was entered into the analysis after the control variables it predicted an additional 28% (adjusted R^2=0.380, p=0.001) of the variance in reading ability. The subsequent inclusion of non-word reading increased this by an additional

22% (adjusted R^2=0.599, p<0.001). When non-word reading was entered after the control variables, it predicted an additional 49% of the variance in reading (adjusted R^2=0.585, p<0.001). Spoonerism only predicted an additional 1% (adjusted R^2=0.599, p<0.001) when entered subsequently. Collectively these two measures of phonological processing/decoding predicted about 50% of the variance in reading; however, non-word reading predicted more unique variance than spoonerism.

Although the OCT predicted a significant amount of the variance in word recognition when entered directly after the control variables (adjusted R^2=0.356, p=0.001, representing an additional 26%) it only predicted an additional 3% once spoonerism, non-word reading and vocabulary were controlled for. The measure of processing speed did not predict a significant amount of the variance in word recognition, even when entered directly after the control variables (adjusted R^2=0.112, p=0.093, representing an additional 1%).

When vocabulary was entered after non-word reading, it predicted an additional 22% (adjusted R^2=0.806, p<0.001) of the variance in reading. Vocabulary and non-word reading collectively account for 71% of the variance in reading ability. Although much of this variance was shared, they both predicted unique variance in word reading.

Table 3.15: Variance in single word reading predicted by the independent variables for the non-dyslexic group. R^2 and adjusted R^2 values with significance levels and percentage increases in variance are displayed.

Predictor Variables	Single Word Reading Non-dyslexics N=28 (17 males, 11 females)			
	R^2	Adjusted R^2	Sig. Level	% inc. Adjusted R^2
Age & Sex	0.066	-0.008	p=0.888	0
+ Block Design & Picture Completion	0.221	0.086	p=0.200	9%
+ Vocabulary	0.561	0.462	p=0.002	37%
+ Complex Non-word Reading	0.573	0.451	p=0.004	0%
+ Spoonerisms Accuracy & Speed	0.698	0.571	p=0.001	12%
+ OCT Accuracy & Speed	0.709	0.537	p=0.005	0%
+ Digit Symbol	0.719	0.525	p=0.009	0%

As shown in Table 3.15, the control variables of age, sex and non-verbal IQ predicted approximately 9% of the variance in reading ability. However, this was non-significant. The inclusion of vocabulary increased the amount of variance predicted by a significant 37%. Non-word reading predicted only a negligible amount of additional variance, but spoonerisms increased the amount of variance predicted by 12%. Orthographic processing and processing speed failed to predict any additional variance in reading ability.

The OCT predicted an additional 12% (adjusted R^2=0.207, p=0.087) and non-word reading an additional 4% (adjusted R^2=0.126, p=0.159) of the variance in reading if entered individually after the control variables. When digit symbol was entered directly after the control variables it did not add anything to the level of prediction (adjusted R^2=0.047, p=0.314).

222

Spoonerisms and vocabulary proved to be the best predictors of word recognition, collectively accounting for approximately 50% of the variability in single word reading after the control variables. When spoonerisms was entered into the analysis after the control variables it increased the amount of variance predicted by 21% (adjusted R^2=0.302, p=0.030). Vocabulary predicted an additional 29% (adjusted R^2=0.593, p<0.001) when entered subsequently. When spoonerisms was entered into the analysis directly after vocabulary it predicted an additional 13% (adjusted R^2=0.593, p<0.001) of the variance in reading ability.

3.3.3.2 Spelling

The current analysis investigated the extent to which phonological and orthographic processing, single word reading, decoding, vocabulary and processing speed predicted individual differences in spelling ability.

Pearson Product Moment correlations were performed in order to identify any relationship between the dependent (spelling) and independent variables. Dyslexic and non-dyslexic groups were analysed separately. Correlations are shown in Tables 3.16.

223

Table 3.16: Correlations between spelling and the predictor variables for the dyslexic and non-dyslexic sample.

	Spelling	
	Dyslexics	**Non-dyslexics**
Single Word Reading	0.716**	0.603**
Vocabulary	0.560**	0.452*
Complex Non-word Reading	0.535**	0.168
Spoonerisms Accuracy	0.406**	0.244
Spoonerisms Speed	-0.437**	-0.286
OCT Accuracy	0.717**	0.431*
OCT Speed	-0.589**	-0.398*
Digit Symbol	0.482**	0.070

** Correlation significant at the 0.01 level

* Correlation significant at the 0.05 level

The spelling ability of the dyslexics was found to be highly correlated with all predictor variables. The spelling ability of the non-dyslexics was found to be highly correlated with the measure of single word reading, less correlated with vocabulary and the OCT (accuracy and speed) and not significantly correlated with non-word reading, spoonerisms (accuracy and speed) or digit symbol.

In order to determine which of the predictor variables accounted for the most variance in spelling ability, regression analyses were carried out. Predictor variables were entered into the analysis following the control variables of age, sex and non-verbal IQ (Block Design, Picture Completion). Single word reading was the first predictor variable entered into the analysis followed by vocabulary, non-word reading, spoonerisms (accuracy and speed), the orthographic choice task (accuracy

and speed), and finally digit symbol. Dyslexic and non-dyslexic groups were analysed separately (see Table 3.17 and Table 3.18).

Table 3.17: Variance in spelling predicted by the independent variables for the dyslexic group. R^2 and adjusted R^2 values with significance levels and percentage increases in variance are displayed.

Predictor Variables	Spelling Dyslexics N=43 (24 males & 19 females)			
	R^2	Adjusted R^2	Sig. Level	% inc. Adjusted R^2
Age & Sex	0.082	0.036	p=0.180	4%
+ Block Design & Picture Completion	0.139	0.048	p=0.213	1%
+ Single Word Reading	0.581	0.524	p<0.001	47%
+ Vocabulary	0.586	0.517	p<0.001	0%
+ Complex Non-word Reading	0.586	0.503	p<0.001	0%
+ Spoonerisms Accuracy & Speed	0.591	0.480	p<0.001	0%
+ OCT Accuracy & Speed	0.691	0.581	p<0.001	10%
+ Digit Symbol	0.729	0.621	p<0.001	4%

As shown in Table 3.17, the control variables of age, sex and non-verbal IQ accounted for a non-significant 5% of the variance in spelling ability. The inclusion of single word reading increased the amount of variance predicted by a significant 47%. Vocabulary, non-word reading and spoonerisms failed to predict any additional variance when entered in subsequent stages of the analysis. The OCT predicted an additional 10% and digit symbol an additional 4% of the variance in spelling ability.

When spoonerisms was entered into the analysis after the control variables, it predicted an additional 15% (adjusted R^2=0.197, p=0.028) of the variance in spelling ability. The subsequent inclusion of non-word reading increased this by an additional 9% (adjusted R^2=0.293, p=0.006). When non-word reading was entered after the control variables, it predicted an additional 25% of the variance in spelling (adjusted R^2=0.296, p=0.003), spoonerism failed to predict any additional variance when entered subsequently. Collectively these two measures of phonological processing/decoding accounted for 24% of the variance in spelling; however, only non-word reading accounted for unique variance.

When the OCT was entered into the analysis after the control variables, it accounted for an additional 40% (adjusted R^2=0.447, p<0.001) of the variance in spelling ability. The subsequent inclusion of spoonerism and non-word reading increased the amount of variance predicted by11% (adjusted R^2=0.563, p<0.001). When the OCT was entered into the analysis after spoonerism and non-word reading – which accounted for 24% of the variance in spelling ability when entered after the control variables (adjusted R^2=0.293, p=0.006) - it predicted an additional 27% (adjusted R^2=0.563, p<0.001). Although variance was shared, orthographic processing appeared to contribute to dyslexic's spelling ability to a greater extent than phonological processing/decoding.

As shown in Table 3.17, non-word reading and spoonerisms failed to predict any additional variance in spelling ability after single word reading. Single word reading, however, continued to predict an additional 24% of unique variance in spelling ability when entered after non-word reading and spoonerisms (adjusted R^2=0.490, p<0.001).

Similarly, vocabulary failed to predict additional variance when entered after single word reading, but contributed significantly when entered before (adjusted R^2=0.385, p<0.001), predicting an additional 34% of the variance in spelling ability after the control variables. Single word reading continued to account for unique variance in spelling when entered into the analysis after vocabulary (adjusted R^2=0.571, p<0.001, representing an additional 18%). In fact, single word reading continued to

226

predict unique variance in spelling ability when entered into the analysis after non-word reading, spoonerisms and vocabulary (adjusted $R^2=0.480$, p<0.001, representing an additional 6%).

Single word reading and the OCT collectively predicted an additional 55% of the variance in spelling ability after the control variables (adjusted $R^2=0.603$, p<0.001). The OCT predicts an additional 8% of variance when included in the analysis after single word reading, which predicts an additional 15% when entered into the analysis after the OCT. Although there is considerable overlap between the variance predicted by reading and the OCT, both variables continue to predict unique variance in spelling ability when the other is controlled for.

When entered directly after the control variables, digit symbol predicted an additional 12% of the variance in spelling ability (adjusted $R^2=0171$, p=0.034). As shown in Table 3.17 this was reduced to 4% when all other variables were controlled for.

Table 3.18: Variance in spelling predicted by the independent variables for the non-dyslexic group. R^2 and adjusted R^2 values with significance levels and percentage increases in variance are displayed.

Predictor Variables	Spelling Non-dyslexics N=28 (17 males, 11 females)			
	R^2	Adjusted R^2	Sig. Level	% inc. Adjusted R^2
Age & Sex	0.032	-0.045	p=0.665	0%
+ Block Design & Picture Completion	0.051	-0.115	p=0.871	0%
+ Single Word Reading	0.541	0.437	p=0.003	44%
+ Vocabulary	0.577	0.456	p=0.003	2%
+ Complex Non-word Reading	0.577	0.428	p=0.008	0%
+ Spoonerisms Accuracy & Speed	0.624	0.436	p=0.015	1%
+ OCT Accuracy & Speed	0.663	0.431	p=0.028	0%
+ Digit Symbol	0.686	0.434	p=0.035	0%

For the non-dyslexics, the control variables of age, sex and non-verbal IQ accounted for a non-significant amount of variance in spelling ability. The inclusion of single word reading increased the amount of variance predicted by a significant 44%. Vocabulary, non-word reading, spoonerisms (accuracy and speed), the OCT (accuracy and speed) and digit symbol predicted only minimal additional variance once single word reading was controlled for.

When entered individually after the control variables, non-word reading, spoonerisms (accuracy and speed), digit symbol and the OCT (accuracy and speed) failed to predicted a significant amount of the variance in spelling ability (adjusted R^2= -0.101, p=0.771 for non-word reading; adjusted R^2= -0.041, p=0.566 for

spoonerisms; adjusted $R^2 = -0.163$, p=0.939 for digit symbol and adjusted $R^2 = 0.104$, p=0.219 for the OCT). When combined, the total variability predicted by these variables remained non-significant (adjusted $R^2 = -0.013$, p=0.505). Although non-significant, the OCT predicted more variance than any of the other variables accounting for an additional 10% of the variance in spelling ability when entered after the control variables.

When entered into the analysis after the control variables, vocabulary accounted for an additional 28% (adjusted $R^2 = 0.284$, p=0.028) of the variance in spelling ability. The subsequent inclusion of single word reading increased this by 18% (adjusted $R^2 = 0.456$, p=0.003). In contrast, vocabulary only predicted an additional 2% of the variance in spelling ability when entered into the analysis after single word reading (see Table 3.18).

3.3.3.3 Reading Comprehension

The current analysis investigated the extent to which phonological and orthographic processing, single word reading, decoding, vocabulary and processing speed predicted individual differences in the ability to comprehend text.

Pearson Product Moment correlations were performed in order to identify any relationship between the dependent (reading comprehension) and independent variables. Dyslexic and non-dyslexic groups were analysed separately. Correlations are shown in Tables 3.19.

Table 3.19: Correlations between reading comprehension and the predictor variables for the dyslexic and non-dyslexic sample.

	Reading Comprehension	
	Dyslexics	**Non-dyslexics**
Single Word Reading	0.634**	0.462*
Vocabulary	0.548**	0.600**
Complex Non-word Reading	0.331*	0.388*
Spoonerisms Accuracy	0.298	0.220
Spoonerisms Speed	-0.424**	-0.415*
OCT Accuracy	0.493**	0.550**
OCT Speed	-0.471**	-0.241
Digit Symbol	0.606**	-0.086

** Correlation significant at the 0.01 level

* Correlation significant at the 0.05 level

The reading comprehension ability of the dyslexics was highly correlated with single word reading, vocabulary, spoonerisms speed, OCT (accuracy and speed) and digit symbol, less correlated with non-word reading and not significantly correlated with spoonerisms accuracy. The reading comprehension of the non-dyslexics was found to be highly correlated with vocabulary and OCT accuracy, less correlated with single word reading, non-word reading and spoonerisms speed and not significantly correlated with spoonerisms accuracy, OCT speed or digit symbol.

In order to determine which of the predictor variables accounted for the most variance in reading comprehension, regression analyses were carried out. Predictor variables were entered into the analysis following the control variables of age, sex and non-verbal IQ (Block Design, Picture Completion). Single word reading was the

first predictor variable entered into the analysis followed by vocabulary, non-word reading, spoonerisms (accuracy and speed), the orthographic choice task (accuracy and speed), and finally digit symbol. Dyslexic and non-dyslexic groups were analysed separately (see Table 3.20 and Table 3.21).

Table 3.20: Variance in reading comprehension predicted by the independent variables for the dyslexic group. R^2 and adjusted R^2 values with significance levels and percentage increases in variance are displayed.

Predictor Variables	Reading Comprehension Dyslexics N=43 (24 males & 19 females)			
	R^2	Adjusted R^2	Sig. Level	% inc. Adjusted R^2
Age & Sex	0.013	-0.036	p=0.765	0%
+ Block Design & Picture Completion	0.053	-0.047	p=0.714	0%
+ Single Word Reading	0.414	0.335	p=0.001	34%
+ Vocabulary	0.426	0.331	p=0.002	0%
+ Complex Non-word Reading	0.469	0.363	p=0.001	3%
+ Spoonerisms Accuracy & Speed	0.500	0.364	p=0.003	0%
+ OCT Accuracy & Speed	0.512	0.338	p=0.009	0%
+ Digit Symbol	0.667	0.534	p<0.001	19%

For the dyslexics, the control variables of age, sex and non-verbal IQ accounted for a non-significant amount of the variance in reading comprehension. The inclusion of single word reading increased the amount of variance predicted to a significant 34%. Vocabulary, non-word reading, spoonerisms (accuracy and speed) and the OCT (accuracy and speed) predicted only minimal additional variance when entered after

231

single word reading. Digit symbol, however, predicted an additional 19% of the variance in reading comprehension when all other variables were controlled for.

When entered individually after the control variables, non-word reading, spoonerisms (accuracy and speed) and the OCT (accuracy and speed) did not predict a significant amount of the variance in reading comprehension (adjusted R^2=0.023, p=0.330 for non-word reading; adjusted R^2=0.083, p=0.166 for spoonerisms and adjusted R^2=0.141, p=0.071 for the OCT).

When entered into the analysis after the control variables, vocabulary accounted for an additional 26% (adjusted R^2=0.380, p=0.002) of the variance in reading comprehension. The subsequent inclusion of single word reading increased this by 7% (adjusted R^2=0.331, p=0.002). Single word reading and vocabulary appeared to share a considerable amount of the variance in common with reading comprehension; although vocabulary failed to predict any unique variance once single word reading had been controlled for (see Table 3.20).

When entered into the analysis after the control variables, digit symbol accounted for an additional 30% (adjusted R^2=0.301, p=0.002) of the variance in reading comprehension. The subsequent inclusion of single word reading increased the amount of variance predicted by an additional 26% (adjusted R^2=0.564, p<0.001). When the order was reversed and digits symbol entered into the analysis directly after single word reading (which predicted approximately 34% of the variance in reading comprehension, see Table 3.20), it predicted an additional 22% (adjusted R^2=0.564, p<0.001) of the variance in reading comprehension. Both of these measures therefore, appear to be predicting unique variance in reading comprehension ability.

232

Table 3.21: Variance in reading comprehension predicted by the independent variables for the non-dyslexic group. R^2 and adjusted R^2 values with significance levels and percentage increases in variance are displayed.

Predictor Variables	Reading Comprehension Non-dyslexics N=28 (17 males, 11 females)			
	R^2	Adjusted R^2	Sig. Level	% inc. Adjusted R^2
Age & Sex	0.009	-0.070	p=0.892	0%
+ Block Design & Picture Completion	0.271	0.145	p=0.108	15%
+ Single Word Reading	0.348	0.200	p=0.075	5%
+ Vocabulary	0.565	0.441	p=0.004	24%
+ Complex Non-word Reading	0.568	0.417	p=0.009	0%
+ Spoonerisms Accuracy & Speed	0.656	0.484	p=0.007	6%
+ OCT Accuracy & Speed	0.807	0.674	p=0.001	19%
+ Digit Symbol	0.821	0.678	p=0.001	1%

For the non-dyslexics, the control variables of age, sex and non-verbal IQ predicted approximately 15% of the variance in reading comprehension. Although non-significant, this level of prediction was far greater than that observed in the dyslexic data. It should be noted that the non-dyslexic sample was considerably smaller than the dyslexic sample. Differences in the levels of prediction should be interpreted accordingly.

Single word reading increased the amount of variance predicted by a non-significant 5%. The subsequent inclusion of vocabulary increased the amount of variance predicted by a significant 24%. Non-word reading failed to predict any additional variance in reading comprehension. Spoonerisms increased the amount of variance

predicted by 6%, the OCT accounting for a further 19%. The inclusion of digit symbol only predicted minimal additional variance in reading comprehension.

When entered individually after the control variables, non-word reading, spoonerisms and digit symbol failed to predict a significant amount of the variance in reading comprehension (adjusted R^2=0.144, p=0.134 for non-word reading, adjusted R^2=0.160, p=0.137 for spoonerisms and adjusted R^2=0.114, p=0.178 for digit symbol). When the OCT was entered into the analysis following the control variables it accounted for an additional 29% (adjusted R^2=0.442, p=0.004) of the variance in reading comprehension. When vocabulary was entered into the analysis after the control variables it predicted an additional 30% of the variance in reading comprehension (adjusted R^2=0.454, p=0.002).

When vocabulary was entered after the OCT it increased the amount of variance predicted by 13% (adjusted R^2=0.568, p=0.001). When the OCT was entered after vocabulary it increased the amount of variance predicted by a further 12% (adjusted R^2=0.568, p=0.001). Vocabulary and the OCT shared variance in common with reading comprehension; however, both predicted unique variance once the other was controlled for.

3.3.4 Discussion

Despite considerable differences in overt reading behaviour, the same skills appeared to underlie the word recognition of both dyslexics and non-dyslexics. For both groups, the best single predictor of word recognition was vocabulary. After the control variables, vocabulary predicted approximately 55% of the variance in reading ability for the dyslexics and 37% for the non-dyslexics. Measures of phonological processing proved to be the next best predictors of word recognition. For the dyslexics, vocabulary and non-word reading predicted approximately 71% of the variance in reading ability, whilst for the non-dyslexics, vocabulary and spoonerisms accounted for approximately 50% of the variance in reading. These findings are consistent with those of Gottardo et al (1997) and Hanley (1997) who also determined that measure of phonological processing and vocabulary represented

reliable predictors of reading ability in adults. Gottardo et al (1997) found a phoneme deletion task (the Auditory Analysis Test) and WAIS vocabulary to be unique predictors of reading ability (assessed by the WRAT) for 73 adults (26 poor readers and 49 average readers) after the variance predicted by age, block design, digit span and measures of non-word repetition, syntactic processing and listening comprehension were controlled for. Similarly, Hanley (1997) found that vocabulary (assessed by the Graded Naming Test) predicted 44% of the variance in single word reading (assessed by the NART) for a group of 33 dyslexic students. Vocabulary and spoonerisms combined predicted 53% of the variance in reading ability. Digit span, a rhyming task and a phoneme counting task did not predict a significant amount of the variance in performance on the NART. The relationship between vocabulary and reading was interpreted by these authors as indicating that individuals with good vocabularies were potentially better equipped to compensate for their decoding/reading difficulties.

The current study also determined that for both dyslexics and non-dyslexics, reading represented the primary predictor of spelling ability. The groups differed, however, in that the spelling ability of the dyslexics also varied as a function of orthographic processing skill. The reading comprehension ability of the dyslexics and non-dyslexics was determined by completely different sets of predictors. For the dyslexics, word recognition and processing speed were the best predictors, whilst for the non-dyslexics, vocabulary and orthographic processing predicted the most amount of variance in performance on the reading comprehension task.

These results are summarised in Figure 3.1 and Figure 3.2.

Figure 3.1: Predictive relationships identified between the dependent and independent variables for the dyslexics.
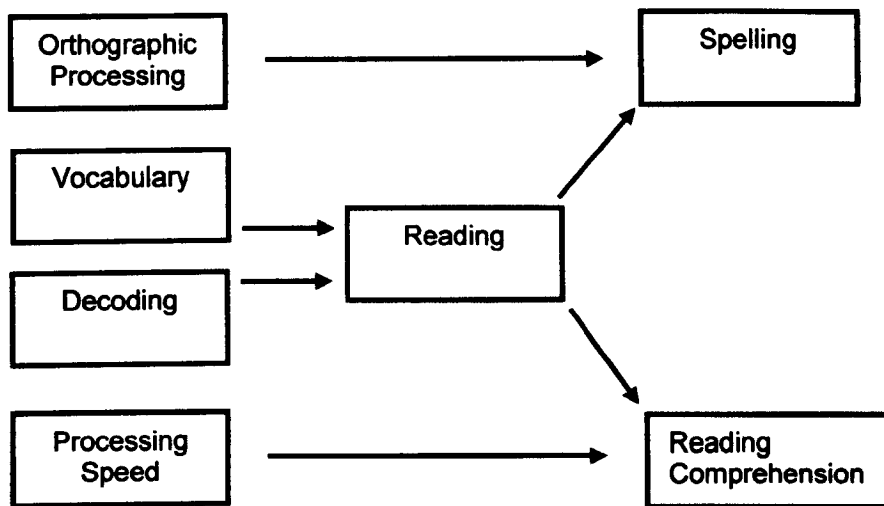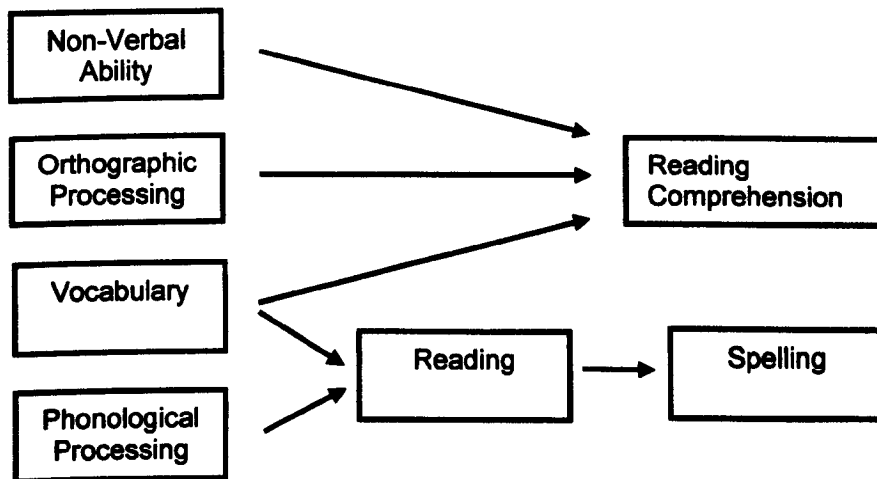

Figure 3.2: Predictive relationships identified between the dependent and independent variables for the non-dyslexic.

236

In addition to vocabulary, decoding ability was found to predict the dyslexic's reading ability. This is consistent with Bruck (1990), who found that dyslexic student's weak word recognition stemmed from their poor understanding of phonology (spelling sound correspondences). Reading, in turn, significantly predicted the dyslexic's performance on the reading comprehension and spelling tasks. Although it is not possible to infer direct causal relationships, the possibility exists that the dyslexic's weak text comprehension and spelling skills are related to their poor decoding ability. Decoding skills could influence reading comprehension and spelling indirectly through their detrimental effects on word recognition. As decoding skills increased, so did word recognition. Similarly, as word recognition proficiency increased, so did performance on the reading comprehension and spelling tasks.

This theory has gained particular support as a means of explaining reading comprehension deficits. For example, the 'Simple View of Reading' (Gough and Tunmer, 1986) would dictate that the dyslexic's decoding skills were below the "threshold level of facility" (cited in Chen and Vellutino, 1997, page 3) and would, therefore, interfere with the dyslexic's ability to comprehend text. In this instance, poor decoding skills affect the accuracy and speed with which information becomes available to language comprehension.

Kitz and Nash (1992) describe Chall's (1983) Stage Theory of Reading Development in which decoding accuracy and fluency are essential prerequisites to reading comprehension. If decoding skills fail to become automatised, they are likely to over-utilise limited processing resources. For example, if phonological/decoding skills are inefficient, the processing required for word recognition will place an additional strain on working memory, restricting the resources accessible to comprehension (Swanson and Alexander, 1997). Interpreted in terms of attentional resources "automaticity of decoding frees attention from the task of decoding and allows the reader to concentrate on comprehending" (LaBerge and Samuels, 1980, cited in Kitz and Nash, 1992, page 19). The hypothesis that the reading comprehension ability of dyslexics is indirectly related to their poor phonological processing/decoding is therefore not theoretically incompatible with the direct relationship identified

between reading comprehension and processing speed if the latter is considered indicative of automatic processes.

As well as compensating for deficient lower-level processes, working memory is involved in virtually every aspect of the reading comprehension process. For example, in order to deduce the meaning of unfamiliar words through the use of contextual information, the reader must retain and integrate consecutive cues pertaining to a word's meaning in working memory. Similarly, the ability to resolve ambiguities within a text requires that all potential interpretations be held in memory, until subsequent information alludes to the correct version. A number of studies have linked poor reading comprehension to an elaborative processing weakness. For example, Simmons and Singleton (2001) and Long, Oppy and Seely (1997) identified a relationship between reading comprehension and inferential processing. Long et al (1997) found that skilled and less skilled readers functioned equivalently with regard to the construction of sentence level representations. The less skilled readers had all the information required to make inferences, but they were deemed "less likely" (page 141) to use this knowledge during the comprehension of more extensive pieces of related discourse. Working memory limitations were implicated as a possible cause of less skilled reader's inferential processing weaknesses. The ability to connect information from different parts of the text and to make subject related inferences, requires the temporary storage and concurrent processing of information in working memory.

To comprehend text is to construct a propositional network, resulting in a coherent memory representation. According to Daneman and Tardif (1987) "the memory is simply a by-product of the processes" (page 504). It is the construction of the propositional network that allows readers to understand text and inferential processing is fundamental to identifying the central concepts or themes within a story and establishing connections between them.

Within the dyslexic sample, processing speed was found to be highly predictive of reading comprehension, as processing speed increased so did performance on the reading comprehension task. This relationship could potentially reflect the attempts

238

of the central executive to compensate for decoding difficulties, elaborative processing difficulties, or both. Irrespective of the mechanism, processing efficiency appears to underlie the reading comprehension abilities of adult dyslexics.

Within the current study, reading accuracy was also found to predict the spelling ability of both the dyslexics and non-dyslexics. Burt and Fury (2000) identified a similar relationship within a sample of non-dyslexic college students. In addition to reading accuracy, which could potentially represent an index of phonological processing/decoding ability, Burt and Fury (2000) found that reading experience also predicted spelling performance. The ability to spell a familiar word requires a precise and complete knowledge of the word's orthography that is dependent on the quality with which the word is represented within the lexicon. It is through reading experience that individuals learn the visual codes for specific words. An individual's sight vocabulary consists of the visual-orthographic codes of words previously encountered in print. It is conceivable that the more a word is encountered in print, the more detailed its representation within the lexicon becomes. Alternatively, the more an individual reads, the more entries they have within their lexicon and, consequently, the greater the degree of specificity required to distinguish between similar items. For example, the representation of the word 'ensure' may be relatively non specific, until the word 'endure' is encountered when it becomes necessary to distinguish between them. According to Burt and Butterworth (1996), exposure to print "may promote the ongoing acquisition of spelling information about familiar and unfamiliar words" (page 6). As evidence for this they sight the findings of Brown (1988), who documented the adverse effect of exposure to misspellings on spelling ability.

As well as differing in terms of exposure to orthographic information, individuals also vary in the extent to which they are able to process and encode orthographic information. The ability to acquire word specific knowledge is perceived as a factor that differs across individuals. Burt and Butterworth (1996) found that competent adult spellers acquired more spelling knowledge during reading than poor spellers. It was suggested that good and poor spellers differed in terms of the underlying skills that allowed for spelling acquisition. The superior phonological and verbal skills of

good spellers facilitated the incidental learning of orthographic detail during reading. Good spellers were considered in advance of poor spellers in terms of their ability to process and learn orthographic information.

In accordance with this hypothesis, orthographic processing was found to predict the spelling ability of the dyslexics within the current study. Those dyslexics with relatively good knowledge of English orthography, and the ability to access and apply that knowledge, appeared to be the better spellers. Although orthographic processing continued to predict variance in the non-dyslexics reading comprehension ability, these individuals may have reached a developmental ceiling in terms of their orthographic processing ability. Their spelling performance was, therefore, better determined by their exposure, through reading, to orthographic information rather than their ability to process that information. The dyslexics, conversely, may continue to process orthographic information inefficiently, a factor that consequently affected their spelling. The nature of the orthographic choice task does not allow us to distinguish between an individual's knowledge of orthography and their ability to retrieve that knowledge. Burt and Fury (2000) deemed a retrieval deficit unlikely, due to the full visual and phonological memory retrieval cues available during the task. However, this might not be the case for a sample of dyslexics.

Generating the pronunciation of test items would not directly distinguish between correctly spelt words and pseudohomophones (e.g. monk and munk). However, accessing phonological representations is one means of activating orthographic representations. According to Landerl et al (1996), orthographic representations within the orthographic lexicon are "phonologically underpinned" (page 3). For skilled readers, orthographic and phonological representations, although distinct, are automatically co-activated during reading and spelling. These connections are essential for automatised lexical access. Bruck (1992) suggests that the link between orthography and phonology is weaker in dyslexics.

Although phonology was not directly implicated in the spelling ability of either group, the possibility exists that it exerts an effect on spelling indirectly through reading. Individuals who experience reading difficulties, possibly as a result of their

poor decoding skills, are less likely to engage in reading to the same extent as proficient readers, thus limiting their exposure to the orthographic information required for spelling. Poor readers are also less likely to provide accurate and/or complete information to the spelling system.

Alternatively, it is possible that some form of compensatory reliance on orthographic processing is in operation as a means of bypassing deficient phonological processing skills. It has been hypothesised within reading research (Frith, 1985; Snowling, 1996) that dyslexics rely on their relatively good visual/orthographic or visual-semantic skills (e.g. use of context) as a means of compensating for their phonological weaknesses (Rack, 1985; Campbell and Butterworth, 1985). Bruck (1993), however, found no evidence indicating that dyslexic's spelling was purely mediated by visual processes, maintaining instead that dyslexic adults used the same linguistic information for spelling (e.g. phonological, orthographic, morphological and visual) as non-dyslexic adults. Although adult dyslexics' knowledge and use of phonological information was less efficient than chronological and spelling age matched controls, they continued to rely on it during spelling tasks. Although the current study acknowledges the possible, indirect (via reading) effect of phonological processing on spelling, a direct relationship was not identified between spelling ability and phonological processing, nor were the predictors of spelling ability the same for dyslexic and non-dyslexic adults.

As mentioned previously, different variables were found to predict the reading comprehension ability of the dyslexics and non-dyslexics. For the non-dyslexics, vocabulary and orthographic processing represented the best predictors of reading comprehension. With regard to vocabulary, two possible mechanisms have been proposed as a means of accounting for its relationship with reading comprehension. Firstly, knowing the meaning of individual words within a text aids comprehension. Secondly, it is not vocabulary per se that facilitates comprehension, but the verbal-semantic skills of which it is an indication. Indeed, the relationship between reading comprehension and verbal-semantic skills has been clearly established within the child literature (Nation and Snowling, 1998). Stothard and Hulme (1996) studied a subgroup of children with specific comprehension difficulties (poor comprehenders)

and found that in the presence of normal decoding skills, weak reading comprehension was caused by general language comprehension difficulties, resulting from deficient verbal-semantic processes or Verbal IQ. Stanovich et al (1996) described vocabulary as one of the "primary tools of verbal intelligence" (page 19) and reading comprehension as "an excellent measure of general verbal ability" (Stanovich & Cunningham, 1992, page 58). Vocabulary and reading comprehension are perceived as highly related, reflecting past and present ability to learn concepts from context respectively (Sternberg, 1987). Within the current study, the ability of vocabulary to predict reading comprehension is potentially a reflection of the fact that verbal ability underlies both of these tasks. The ability to make inferences, to integrate sentences and information contained in different parts of the text, and to induce word meanings are skills possessed by the verbally competent and are essential to the comprehension of written material.

An additional variable known to interact with vocabulary and reading comprehension is exposure to print. Stanovich and Cunningham (1992) found evidence suggesting that exposure to print could "compensate for modest levels of general cognitive ability" (page 60). Stanovich et al (1996) and Nation and Snowling (1998) reconcile these contrasting positions (i.e. the ability to learn verses the number of learning opportunities) by proposing the existence of a reciprocal relationship (The 'Matthew Effect') between reading comprehension and exposure to print. Individuals with good verbal skills have more productive reading experiences, in that they are able to benefit more from contact with linguistically loaded material. Exposure to print aids the development of comprehension skills, which in turn facilitates further gains in verbal ability.

Orthographic processing also predicted the reading comprehension ability of the non-dyslexics. Orthographic processing represents a skill that is also believed to be influenced by exposure to print (Stanovich and West, 1989). The more an individual reads, the more automatised their word recognition becomes (Stanovich et al, 1996) and the more adept they become at processing text in general. Efficient orthographic processing could aid reading comprehension in that it facilitates automatic word recognition. Through accessing their sight vocabulary, individuals are able to

recognise words they have seen before without having to decode them. As mentioned previously, if word recognition is automatised and efficient then processing resources/attention become available to comprehension.

The above discussion suggests the following developmental processes. During literacy development, in the absence of a phonological deficit that reduced reading accuracy and fluency, the non-dyslexics were better able to acquire linguistic information (including knowledge of orthography and word meanings) during reading. As proficient readers, the non-dyslexics were also more likely to have engaged in the act of reading to a greater extent than poor readers for whom the process was timely and laborious. Rack (1997) maintained that "even if reading skills develop to acceptable standards, dyslexics tend to read less and thereby limit their opportunities to acquire new vocabulary and new information" (page 68). As a consequence of their increased exposure to print, the non-dyslexic's word recognition, word knowledge and ultimately their reading comprehension and spelling benefited. In contrast, the delayed and inefficient literacy development of the dyslexics could potentially have disrupted their reading experiences restricting their exposure to print, with all its advantages.

3.3.5 Modifications and Future Research

As described previously (see section 3.1.5) a number of the measures investigated in Study VI were designed for use with children. In addition to problems with ceiling effects a related issue concerns the potential consequences of altering these measures to make them suitable for adults. For example, the current study used the NFER Reading Comprehension Test (1975), which had an upper age limit of 15.11. In accordance with the recommendations outlined in the National Working Party's Report on Dyslexia in Higher Education (1999), a 15 minute time limit was imposed when testing adults. According to Simmons and Singleton (2000), this improves the ability of the test to discriminate between dyslexics and non-dyslexics, but reduces validity and introduces the confounding factor of reading speed. Given that the current findings indicated that processing speed predicted the dyslexics' reading comprehension, the dyslexics' comprehension difficulties cannot be unambiguously

243

attributed to difficulties extracting meaning from text, but could be a product of problems with information processing speed.

The need for valid and reliable tests of comprehension, phonology and orthography suitable for adults is discussed in chapter 4 which highlights some of the practical issues of adult assessment.

In addition to examining the extent to which cognitive abilities predict literacy skills, future research could consider factors such as educational background and socioeconomic status. For example, the age at which an individual was diagnosed as dyslexics and any subsequent remedial input could be contributing to the variability between dyslexics. This may be particularly pertinent when considering adults in tertiary education.

3.4 Summary of Chapter 3

The non-dyslexic adults significantly outperformed the dyslexics on measures of vocabulary, auditory short term memory and processing speed. The performance of the non-dyslexics was also significantly in advance of the dyslexics on all measures of literacy (including reading, spelling and reading comprehension), phonology and orthography. With the exception of the two measures of non-verbal IQ, all of the tasks used in the current study represent efficient means of distinguishing between typical dyslexic and non-dyslexic adults.

Section 3.2 demonstrated that is was possible, using various criteria to divide a sample of adult dyslexics into phonological and surface subtypes. In this respect, the findings seem consistent with Castles and Coltheart (1993). However, subsequent analyses designed to assess the utility of the phonological/surface classification system determined that the validity of the subtypes was questionable.

Section 3.3 demonstrated that the same skills appeared to underlie the word recognition of both dyslexics and non-dyslexics. For both groups, vocabulary and phonological processing/decoding ability predicted variance in word recognition. Similarly, reading represented the primary predictor of spelling ability for both dyslexics and non-dyslexics. The groups differed, however, in that the spelling ability of the dyslexics also varied as a function of orthographic processing skill. The reading comprehension ability of the dyslexics was predicted by word recognition and processing speed, whilst for the non-dyslexics, vocabulary and orthographic processing predicted variance on the reading comprehension task.

4. DISCUSSION

4.1 Overview of findings

4.1.1 Sex Differences

Chapter 2 investigated the possibility that dyslexic symptoms differ between males and females, in order to determine whether sex differences could account for any of the variability observed between dyslexics. Across several studies, behavioural and cognitive sex differences were examined. The extent to which the assessment process, from initial referral to formal diagnosis, could contribute to the high proportion of males within dyslexic populations was addressed. The effect of sex differences on response to different methods of remedial instruction was also investigated.

4.1.1.1 Behavioural Sex Differences

Chapter 2 investigated two possibilities whereby behaviour could result in a greater incidence of male referrals. The first of these maintained that males were rated as more disruptive than females and were consequently more likely to be referred for assessment even though the sexes did not differ academically. Although males were rated as more disruptive than females they were also worse at reading. Either of these factors could, therefore, be contributing to the increased number of male referrals. In addition, if referral was a response to behaviour then individuals within the specialist school should, on average, have been rated as more disruptive than individuals within the non-selected school, this was not found to be the case. However, the dyslexics within the specialist school were rated as significantly more hyperactive and emotional than the non-dyslexics within the specialist school, suggesting that dyslexia is related to increased hyperactivity and emotional symptoms.

A second possibility, that behavioural problems were a response to academic failure was also investigated. This was not found to be the case. The relationship between reading ability and behaviour appeared larger within the non-selected school compared to the specialist school. Since a third of the specialist school consisted of

dyslexics who could potentially be experiencing behavioural/emotional problems as a response to their academic difficulties, this result was contrary to prediction. However, the specialist school also significantly outperformed the non-selected school on the reading task. Hence this second possibility was tested further by focusing on the specialist school.

Consistent with the idea that behavioural problems are a response to academic failure, hyperactivity was significantly correlated with reading ability amongst the specialist school children. As hyperactivity increased, reading ability decreased. When the sample from the specialist school was reduced to include only dyslexics and non-dyslexics (i.e. individuals included on the schools special needs register for difficulties other than dyslexia were removed), this relationship appeared specific to females. Although males were more hyperactive, reading ability only appeared to vary in accordance with hyperactivity in females. No relationships were identified between the reading ability and the behavioural ratings of males. These finding failed to support the hypothesis that males become more disruptive and females more withdrawn when they experience learning difficulties. In fact, these results suggest the opposite.

When the dyslexics and non-dyslexics within the specialist school were analysed separately, the results indicated that the dyslexics' reading ability was negatively correlated with hyperactivity and positively correlated with emotional symptoms. Although consistent with the idea that hyperactivity and emotional symptoms are related to dyslexia, these findings suggested that the more emotional the dyslexic, the better their reading. Negative correlations were also identified between the reading ability of the non-dyslexics and emotional symptoms and conduct problems.

When dyslexic, non-dyslexic, males and females were analysed separately, the relationship between the different behavioural ratings and reading appeared larger in females, especially amongst dyslexic females. Again, contrary to prediction the direction of these relationships suggested that the more badly behaved the dyslexic female, the better her reading.

Overall, these findings do not specifically support the position that behavioural factors are related to the increased number of male dyslexics reported in the literature.

4.1.1.2 Cognitive Sex Differences

In addition to behavioural differences, cognitive differences between the sexes could also be contributing to the disproportionate number of male dyslexics. In this instance, the way we define and assess dyslexia could affect the number of males and females diagnosed. Subsequent sections in Chapter 2 examined this possibility by investigating the relative performance of males and females on the Bangor Dyslexia Test and various WISC profiles traditionally associated with dyslexia.

Section 2.4 identified a sex bias on one out of the seven Bangor subtests. Females were found to significantly outperform males on months forwards. Since this subtest distinguished between dyslexics and non-dyslexics (males and females) this difference was considered to be of little practical significance. Providing the Bangor is used as its author intended (as a guide to clinical diagnosis that should be considered alongside literacy levels and evidence on an ability / attainment discrepancy), the impact of this small bias should remain minimal. In other words, the female superiority on this task should not result in a female dyslexic failing to be appropriately diagnosed. As dyslexia is defined on the basis of a constellation of symptoms, sex differences on a single task should not interfere with the diagnosis of the individual dyslexic.

Section 2.6 examined the performance of dyslexic and non-dyslexic females on the ACID and AVID subtests. In contrast to findings reported in the literature, which indicated that non-dyslexic males significantly outperformed dyslexic males on three or more of the ACID tests (see section 2.5.1), information was the only subtest on which the non-dyslexic females significantly outperformed the dyslexic females. Therefore, these profiles did not appear to distinguish between dyslexic and non-dyslexic females.

Section 2.7 contrasted the performance of dyslexic males and females on WISC-III[uk]. Dyslexic females outperformed dyslexic males on the digit span, coding and symbol search subtests and consequently on the index of processing speed (coding and symbol search). Females outperformed males on two of the ACID, one of the AVID and three of the SCAD subtests.

In section 2.8 the relationships between sex of the dyslexic and the ACID, AVID and SCAD factor scores were specifically investigated, together with their influence on reading, spelling and phonological processing. Dyslexic females significantly outperformed dyslexic males on the reading, spelling and phonological processing tasks. Similarly, the ACID and SCAD factor scores obtained by the females were significantly higher than those obtained by the males. However, no difference was identified between the sexes on the AVID factor. The substitution of coding, a task on which the performance of males and females differed significantly, with vocabulary, where the groups did not differ, probably underlies the lack of group differences on the AVID factor.

The ACID, AVID and SCAD factor scores were found to be highly correlated with reading and spelling for both groups; however, the extent to which these factors correlated with phonological processing ability was considerably reduced in females relative to males.

Further analyses investigated whether the best predictors of literacy skills amongst dyslexics varied for males and females. For dyslexic males, arithmetic and spoonerisms predicted the most amount of variance in reading whilst spoonerisms and vocabulary predicted spelling. For dyslexic females, information was the single best predictor of both reading and spelling, with additional variance in spelling predicted by arithmetic. Vocabulary was the best single predictor of phonological processing ability for males and females with additional variance predicted by arithmetic for males only.

Overall, these findings provide some support for the position that males and females differ cognitively (even those diagnosed as dyslexic) and that these differences may

effect the manifestation of dyslexia related problems (e.g. poor literacy) between the sexes. However, these differences may not necessarily have an impact on assessment measures, such as the Bangor Dyslexia Test. Therefore, whether these cognitive differences lead to the over-representation of males in the dyslexic population has yet to be determined.

4.1.1.3 Sex Differences and Remediation

Understanding individual differences including sex differences is of both theoretical and practical importance. At a theoretical level, such understanding strengthens the concept of dyslexia and could potentially inform with regard to its biological or cognitive underpinnings. At a practical level, knowing how male and female dyslexics differ has implications for both assessment and remediation. For example, understanding sex differences could aid in the development of teaching strategies tailored to the needs of each sex. This is particularly pertinent given that the sex differences literature has suggested a female learning style that was more congruous with linguistic or phonic approaches to instruction and a male learning style that was more reliant on visual strategies. Given that research on dyslexia has suggested that learning style differences may determine the impact of a remediation approach, sex differences might be predicted in outcome following different instruction methods. Therefore the final section of Chapter 2 (section 2.9) examined the response of dyslexic and non-dyslexic males and females to different methods of spelling instruction (e.g. a phonics based method and a visual-semantic method).

The results indicated that the type of intervention and the sex of the subject had a non-significant effect on the spelling improvements made by either group. Contrary to predictions, females (dyslexic or non-dyslexic) did not demonstrate greater improvements when instructed by the phonics method, nor was there any evidence that males (dyslexic and non-dyslexic) showed greater advances when instructed via a visual-semantic technique. Further analyses of dyslexic data, concerning the rate and endurance of spelling improvements, also failed to identify an effect of sex or method of instruction. Rather than differing as a function of sex, reading ability was found to predict the dyslexic's spelling improvement. Overall these findings suggest

250

that sex differences may not be useful as a predictor of teaching/remediation outcome amongst dyslexic individuals.

4.1.2 Subtypes and Severity

Whereas Chapter 2 examined the possibility that cognitive sex differences were contributing to the symptom diversity observed between dyslexics, Chapter 3 investigated this diversity by examining potential subtypes and predictors of symptom severity. The extent to which a sample of adult dyslexics could be divided into discrete and meaningful subtypes was investigated.

Section 3.1 compared the performance of dyslexic and non-dyslexic adults on a range of measures based on those used to assess children and, in some cases, those which research has suggested could be used to assess adults. Findings indicated that the non-dyslexics significantly outperformed the dyslexics on measures of single word reading accuracy (including regular, irregular and non-word reading), spelling, reading comprehension, phonological and orthographic processing, vocabulary, digit span and digit symbol. The non-dyslexics also performed all timed tasks significantly faster than the dyslexics. No differences were identified between the dyslexics and non-dyslexics on the two measures of non-verbal IQ.

Section 3.2 demonstrated that is was possible, using various criteria to divide a sample of adult dyslexics into phonological and surface subtypes. In this respect, the findings seem consistent with Castles and Coltheart (1993). However, subsequent analyses designed to assess the utility of the phonological/surface classification system determined that the validity of the subtypes was questionable. For example, irrespective of whether these subtypes were derived from different underlying causes (e.g. inefficient lexical or sublexical functioning) or from different degrees of phonological impairment, the phonological dyslexics should have performed relatively poorly on additional phonological processing tasks. However, on no measure of phonological processing was the performance of the phonological dyslexics worse than that of the surface dyslexics. The subtypes identified within the current study therefore lacked reliability when evaluated against external, parallel

measures, independent of those used to classify the groups. Furthermore, when the occurrence of these subtypes was compared across a number of studies only minimal continuity across different age ranges and classification procedures was apparent. These findings cast doubt on the efficacy of Castles and Coltheart's (1993) procedure as a practical means of explaining individual differences amongst adult dyslexics.

Despite the differences in overt reading behaviour, section 3.3 determined that the same abilities appeared to underlie the word recognition skills of both dyslexics and non-dyslexics. For both groups, vocabulary and phonological processing/decoding ability predicted variance in word recognition. For both dyslexics and non-dyslexics, reading represented the primary predictor of spelling ability. The groups differed however, in that the spelling ability of the dyslexics also varied as a function of orthographic processing skill. The reading comprehension ability of the dyslexics and non-dyslexics was determined by completely different sets of predictors. For the dyslexics, word recognition and processing speed were the best predictors, whilst for the non-dyslexics, vocabulary and orthographic processing predicted variance in performance on the reading comprehension task.

4.2.1 The use of WISC Profiles to Diagnose Dyslexia

The findings of Chapter 2 suggest the ACID, AVID and SCAD profiles do not adequately described the performance of dyslexic females. If full (e.g. 4 out of 4) or even partial (e.g. 3 out of 4) profiles were required for diagnosis, only a very small percentage of the dyslexic females studied in section 2.7 would have been diagnosed as dyslexic. The findings of section 2.6 also suggest that these profiles fail to characterise the performance of dyslexic females, as only one of the ACID and AVID and none of the SCAD subtests (symbol search was not included) distinguished between the dyslexic and non-dyslexic females. Contrary to the literature reviewed in section 2.5.1, these profiles were not particularly representative of the male dyslexics either, with only digit span and coding representing relative weaknesses for the male dyslexics studied in section 2.7. Again, had full or partial profiles been a prerequisite to a diagnosis of dyslexia, very few of the males would have been considered dyslexic.

These results suggest that full ACID, AVID and SCAD profiles do not characterise the performance of dyslexic children. In accordance with the conclusions of Ward et al (1995) and Frederickson (1999), these profiles appear to be of limited practical utility. However, poor performance on digit span and coding appeared to be associated with dyslexia in males and performance on information was related to dyslexia in females.

The extent to which these profiles characterise the performance of dyslexic adults has yet to be determined, although the findings reported in Chapter 3 on WAIS profiles suggest that dyslexic adults may indeed under-perform on these measures compared to their peers. Examining the same individuals at different ages may determine whether the disparate findings identified between the child and adult data reported in this thesis are products of the specific individuals within each sample or whether the nature of dyslexic difficulties changes over time. For example, the current findings suggest that deficits on coding do not characterise dyslexic female children but are apparent within the profile of female dyslexic adults. The extent to

which the ACID, AVID and SCAD profiles represent the performance of adult dyslexics could be investigated, as the current findings suggest that these profiles may be more representative of dyslexic adults than children. Such age by sex interactions would be an interesting course of further investigation and may help explain findings in the literature that indicate that individual children may meet a discrepancy criteria for dyslexia at one point in their development but not at another (eg, Shaywitz, Escobar, Shaywitz, Fletcher and Makugh, 1992).

4.2.2 Spelling Instruction

The findings of section 2.9 suggest that each dyslexic needs to be treated as an individual. For example, some dyslexics made greater spelling gains with the phonics method, others with the visual semantic method. Some showed no preference, either responding well to both, or not really improving as a result of either. Gender did not predict the individual dyslexic's response to different spelling interventions. Sex differences are, therefore, of limited practical significance and, based on these data, do not need to be given great consideration when devising the type of remedial programme for dyslexics.

Although theses findings did not identify a specific method of instruction best suited to the dyslexics, they provided insight into some of the problems encountered by dyslexics, and the extent of the ability differences between the dyslexics and their non-dyslexic class mates. Some of the most striking findings pertained to the dyslexics low maintenance rates, and their perceived inability to monitor their own performance. McNaughton, Hughs and Clark (1994) in a review of 27 studies of spelling instruction, determined that the average time allocated per day within schools for the teaching of spelling was ten minutes. This conforms to the recommendations for non-dyslexic students, who incidentally acquire 500 new words in Grade 4 (age 9-10) and an additional 800 words in grade 5 (age 10-11) through exposure to print. In order to support this rate of acquisition, dyslexics would need to be taught four new words a day. This does not appear such a daunting task until considered within the context of the current findings. Four words per day equates to 12 words after three days of instruction. The dyslexics in the present study

successfully acquired a mean of 6.4 new spellings following the phonics intervention and 5.8 new spellings following the visual-semantic intervention. After only three days, the dyslexics were 50% behind the target number of words required to keep them at a level consistent with their peers. The extent to which the dyslexics are likely to fall further behind is compounded by their low maintenance rates. For example, post-test scores were approximately halved after only three weeks. If the dyslexics had been assessed after six weeks it is likely that scores would have been reduced still further. A spelling programme that promotes generalisation, i.e. the ability to independently apply the spelling strategy to the learning of novel or forgotten words is vital.

The dyslexics within the current study also appeared to have considerable problems with self correction. Observations during the study indicated that the dyslexics experienced considerable difficulties checking and monitoring their spelling behaviour. The following represents an example that characterizes the dyslexic's performance in general.

Whilst taking part in the phonics intervention a subject produced 'inthosates' for the target word 'enthusiastic'. During the progress tests for the phonics intervention, subjects were repeatedly primed to silently read their responses, to establish if they 'sounded right'. They were encouraged to treat their responses as novel words that they were decoding for the first time. Subjects were asked to beat out the syllables and sound out 'what they had written, not what they thought they had written'. Despite the fact that 'in-thō-sātes' consists of only three syllables the subject beat the target five and replied 'ĕn-thū-sĭ-ăst-ĭc' when asked to sound out their response. Error imitation, during the subsequent instructional session, demonstrated that the subject had an awareness of the sounds made by short 'i' and 'e', long 'o' and 'u' and was able to distinguish between them. The subject appeared to understand how their response differed from the target word when explicitly guided by an adult. This individual appeared to demonstrate difficulties independently monitoring the correctness of their response, and this was typical of the dyslexics in general. Any spelling strategy that is going to be effective for dyslexics needs to promote the student's ability to control their own learning.

The finding that dyslexics would need to be given different spellings to their class mates in order to make the two groups comparable suggests that when dyslexics are educated in mainstream schools they should be given different spellings to their non-dyslexic peers. This is typically managed through spelling groups. For example, the more intellectually able or less severely impaired poor spellers would be exposed to the same word lists as the good spellers. This is done to maintain interest, improve vocabulary (especially if the lists contain subject related vocabulary) and encourage recognition when reading. The child then selects (subject to negations with teacher) a target number of words from the list (e.g. 5 out of the 20 words) which are learnt as spellings. During the end of week spelling test, although the child is encouraged to attempt all words, they are specifically assessed on their target 5. The really poor spellers or less able children within a class would be given completely different spelling lists taken from whatever spelling scheme (e.g. Spelling Made Easy, Brand, 1986) they were following. Ideally the dyslexic would take their class spellings to their remedial lessons where the Dyslexia Specialist would teach the spellings using a variety of strategies. The class teacher would then encourage the dyslexic to use those spellings in their everyday class work. Learnt spellings need to be used in meaningful and practical situations. Learning to spell is, after all, "a means to an end" and should be "designed to serve a real purpose" (Graham and Voth, 1990, page 454). For children receiving remedial instruction, communication between class teachers and dyslexia specialists is imperative.

Differentiated spelling groups need to be managed with a reasonable amount of sensitivity. As detailed in section 2.2, dyslexic children often suffer from considerable reductions in self esteem. It would be undesirable for these children to perceive themselves as 'in the bad spelling group'. This is, however, preferable to the weekly failure that these children would undoubtedly suffer if forced to attempt the same spellings as their class mates. Forcing children to learn spellings that are so far in advance of their capabilities teaches them nothing except frustration and failure. One of the most rewarding aspects of this study was the way the intervention was received by teachers, parents and especially the children, who were so encouraged by their perceived progress.

4.2.3 Identifying Dyslexia in Adults

The findings of section 3.1 suggested that dyslexic adults continue to experience difficulties on a range of literacy tasks, including single word reading accuracy, spelling and reading comprehension. On all three measures, the performance of the dyslexics was significantly worse than that of the non-dyslexics. Although the dyslexic's reading and spelling could be regarded as 'compensated' (i.e within the average range), the dyslexics, but not the non-dyslexics, were found to be significantly underachieving on these tasks when compared to an estimated measure of non-verbal functioning. Contrary to predictions derived from the literature, single word reading accuracy was found to represent a continuing area of weakness for the adult dyslexics within the current sample.

These findings support the continued use of a discrepancy criteria along the lines of that advocated by Miles (1993) when assessing adult dyslexics. Although such a discrepancy may not be the only criteria for assessment, relatively poor literacy levels in contrast to good non-verbal ability may provide an important factor in the assessment profile. The fact that the dyslexics' reading and spelling ability fell within the average range for their age, could be misleading if evidence of an ability / attainment discrepancy is not investigated. For example, the dyslexics within the current study presented as 'normal' on these tasks until their performance was compared to their level of underlying ability or non-dyslexics at an equivalent level of education. The battery of tests used to assess dyslexia in adults would therefore need to include measures of a range of abilities.

In addition to reading and spelling, an adult assessment battery should include measures of reading comprehension. However, very few measures are available for adults. The current study used the NFER Reading Comprehension Test (1975), which had an upper age limit of 15.11. Although the NFER-Reading Comprehension Test was acceptable for research purposes, it may be of limited use to the practitioner assessing individual dyslexic adults as without adult norms there would be no way to objectively evaluate the dyslexics' performance against an appropriate population parameter.

There appears to be a considerable need for valid and reliable tests of comprehension suitable for adults. A factor to consider when devising such tests would be the type of comprehension task. There are different ways of assessing reading comprehension, and differences between dyslexics and non-dyslexics could vary dependent on the method adopted. For example, Everatt (1997) found that a cloze procedure for assessing comprehension showed greater differences between dyslexic and non-dyslexic adults than a task that required subjects to read passages and then answer multiple choice questions. In the cloze procedure, a written output may confound reading comprehension with writing-related problems. The NFER reading comprehension test used in the current study adopted the 'passage reading followed by multiple choice questions' procedure. There are a number of factors that need to be considered when assessing comprehension in this way. For example, the length of the passage needs to be considered, as does whether the testee is required to read silently or aloud. Whether access is provided to the passage when answering questions needs to be decided, as does the type of questions asked (e.g., inferential or literal). Finally, the mode of response also needs to be considered. Everatt (1997) suggested that requiring dyslexics to generate written responses may compound their difficulties. Tasks that allow subjects to respond verbally or select one of several options may be easier for dyslexics. There is a need for future research to consider which type of task best identifies differences between dyslexic and non-dyslexics yet still provides a basis on which to assess reading comprehension. Studies that investigate the relationship between different comprehension tasks may be a starting point as they may indicate whether such tests are measuring comprehension (i.e. the ability to extract information from text) or whether variance in scores on these tests are mainly determined by processes that may be dyslexia-related (e.g. processing speed / working memory processes).

As well as reading comprehension, an adult assessment battery should include measures of reading speed. The dyslexic adults within the current study took significantly longer to read lists consisting of regular, irregular and non-words, indicating that word recognition and decoding skills remained effortful and timely. As with comprehension, there are different ways of assessing reading rate. The current study assessed single word recognition speed and decoding speed (i.e. non-

word reading speed). An alternative would be passage reading rate. Future research could investigate which of these best distinguishes between dyslexic and non-dyslexic adults. For example, single word reading tasks may be harder than passage reading tasks due to the lack of semantic or contextual information. Similarly, non-word reading may be better assessed via single items lists rather than text incorporating non-words.

The dyslexics within the current study also showed evidence of poor phonological processing skills across a range of measures (e.g. spoonerisms, non-word reading, alliteration and rhyme fluency), suggesting that problems with phonology also extend into adulthood. The time taken to complete the spoonerisms task represented a particularly good means of discriminating between dyslexic and non-dyslexic adults. The findings of the current study support the conclusions of Bruck (1992) and Gottardo et al (1997) that phonological processing deficits characterise dyslexics of all ages and should be used during the assessment of adults. As with measures of reading comprehension, adult norms would be required.

In addition to phonological processing, orthographic processing deficits distinguished between dyslexic and non-dyslexic adults. The orthographic choice task (OCT) used in the current study was designed for use with children (Olson, 1985) and, as described in section 3.1, approximately 14% of the dyslexics scored full marks. Future research could devise a more challenging OCT, suited to the assessment of adults. For example, this could include harder stimulus words (e.g. anamoly, idiosyncracy, caesarian, diptheria and opthalmologist) or having to choose between more than two options. The extent to which orthographic processing distinguishes between dyslexic and non-dyslexic children could also be investigated. Like deficits on vocabulary and semantic fluency, poor performance on measures of orthographic processing may represent one of the 'long term consequences' of poor reading and could potentially be more characteristic of older rather than younger dyslexics.

Digit symbol (coding) comes under the WISC/WAIS index of processing speed, but may also provide an indication of language processing efficiency. According to

Turner (1997), this 'language-like' task "may offer a summation of the efficiency of the whole language-processing system" (page 56). This hypothesis would be consistent with the finding that on all timed tasks (whether phonological or orthographic) the dyslexics were considerably slower than the non-dyslexics. The performance of the dyslexics was characterised by a lack of fluency or automaticity. Timed tasks, therefore, present as an efficient means of distinguishing between dyslexic and non-dyslexic adults.

In section 3.1.1 it was suggested that 'the diagnosis of dyslexia in adults may not be a case of simply creating age-appropriate versions of measures designed to assess children'. However, on the basis of the current findings, the procedures implied in this statement do not seem so inappropriate. As with children, the diagnosis of dyslexia in adults should satisfy both discrepancy and deficit criteria. Furthermore, the cognitive basis of dyslexia, assumed within the deficit criteria, appears to remain consistent across the life span.

4.3.1 Sex Differences in Dyslexia

Dyslexic symptoms were found to vary between the sexes, with females outperforming males on months forwards (Bangor Dyslexia Test), digit span, coding, symbol search (WISC-III^{UK}), and on measures of reading, spelling and phonological processing. With regard to months forwards it appeared that dyslexic females experienced difficulties with this task less frequently than dyslexic males. Similarly, whereas dyslexic males demonstrate relative weaknesses on digit span and coding, females only showed a slight weakness on digit span, achieving high average to above average scores on coding, which did not present as a relative weakness within their profile.

The findings of section 2.6 are consistent with the idea that deficits on digit span and coding do not characterise dyslexia in females to the same extent as they do dyslexia in males. For example, the performance of dyslexic and non-dyslexic females did not differ on these tasks. However, the findings derived from the adult data, investigated in Chapter 3 suggest the opposite. Digit span and digit symbol distinguished between dyslexic and non-dyslexic adults irrespective of sex (i.e. non-dyslexic males outperformed dyslexic males and non-dyslexic females outperformed dyslexic females). Furthermore, whereas section 2.7 found that dyslexic female children outperformed dyslexic male children on digit span and coding, no differences were identified between male and female adult dyslexics on these tasks. These findings would appear to suggest that deficits on digit span and coding/digit symbol are more characteristic of adult dyslexic females than female dyslexic children and that the severity of these deficits does not appear to vary as a function of sex in adults, whereas it does in children.

The possibility exists that deficits on digit span and coding are not as obvious in young dyslexic females due to the way these tests are standardised. Digit span and coding embody a number of the verbal and perceptual skills at which females excel and the female superiority on these tasks is well established. For example, the original 1974 standardisation, the Scottish 1987 standardisation and the 1982 Dutch

standardisation of the WISC all showed a female advantage on these measures. In the case of coding, this advantage was approximately half a standard deviation. Turner (1997) described how these 'normative sensitivities' could interfere with the diagnosis of dyslexia. By comparing the individual's performance to a standardisation sample consisting of males and females, "boys are more likely, and girls less likely, to have their scores deemed as exceptionally low. To attract a dyslexia diagnosis, a girl must perform at a lower level than a boy on these two tests" (page 67-68). Since cognitive sex differences are far more pronounced prior to puberty and gradually decrease with age, deficits on digit span and digit symbol may be more easily identified in adult dyslexic females. If deficits on digit span and coding are associated with dyslexia in female children, but are masked by comparisons with a standardisation sample consisting of males and females, comparing female dyslexics to 'normal' females, should determine their true level of underachievement. The dyslexic and non-dyslexic females compared in section 2.6 did not differ on digit span or coding, suggesting that the dyslexic females were not underachieving on these tasks. Rather than the testing procedure masking their difficulties, the dyslexic females studied Chapter 2 did not appear to be experiencing any difficulties with these measures. An alternative possibility is that female dyslexics fall behind with maturity. In other words, the female dyslexic's ability to perform these tasks does not develop in accordance with the age based improvements made by non-dyslexic females.

Since the adult dyslexics in Chapter 3 were only assessed on a limited number of WAIS-R subtests it is not possible to determine whether digit span and digit symbol would have represented relative weaknesses within their profile. Although, of the five subtests administered, the adult dyslexics obtained their lowest scores on these measures. The combined results of sections 2.6 and 2.7 suggest that a task may distinguish between dyslexic and non-dyslexics, even though it does not present as a weakness for the dyslexics. For example, the non-dyslexics females significantly outperformed the dyslexic females on information, suggesting that dyslexic and non-dyslexic females perform differently on this task which could therefore be used to diagnose dyslexia in females. However, information was the third highest mean scaled score obtained by the dyslexic females in section 2.7, and only represented a

relative weakness for 8% of the dyslexic females. This suggests that deficits on information are not associated with dyslexia in females. Although information statistically distinguished between dyslexic and non-dyslexic females, it is unlikely that the performance of the individual dyslexic female will be characterised by deficits on this task. Frederickson (1999) refers to this inconsistency as a frequent cause of confusion, maintaining that findings derived from between group comparisons "cannot be used to support conclusions about diagnostic utility with individuals" (page 5).

The information subtest also represented the single best predictor of the dyslexic females reading and spelling ability. This subtest assesses the ability to retain factual information and to a certain extent exposure to that information. The reading and spelling ability of the dyslexic females appeared related to these 'environmental' factors, e.g. exposure to print and educational opportunity. In contrast, the reading and spelling ability of dyslexic males was predominantly predicted by arithmetic and spoonerisms. Arithmetic is often perceived as assessing phonological memory, due to the "almost unlimited central role of verbal learning and mediation" (Turner, 1997, page 60). Similarly, spoonerisms assesses phonological processing, including phonological awareness and the ability to maintain and manipulate phonological information within short term memory. The reading and spelling ability of dyslexic males was therefore predicted by the skill deficits typically associated with dyslexia (e.g. phonological processing). These results suggest that the cognitive deficits that define dyslexia are more related to dyslexia in males. Although predicted by similar measures (e.g. vocabulary), female dyslexics manifest superior phonological processing ability and, compared to their male counterparts, this ability appeared to be less related to their ACID, AVID and SCAD factor scores and their reading and spelling ability.

The current research suggests that dyslexic female children do not manifest the clinical symptoms associated with dyslexia to the same extent as dyslexic male children. As such, sex differences may be contributing to the individual variation observed across dyslexics. The exact nature of these differences remains unclear. For example, dyslexic males may experience certain deficits more frequently (e.g.

months forwards) or more severely (e.g. digit span and spoonerisms) than dyslexic females. Alternatively, dyslexia in females may be qualitatively different to dyslexia in males, possibly resulting from different underlying causes. For example, literacy difficulties in males could result from phonological processing deficits, whilst literacy difficulties in females may be more related to exposure to print and educational opportunity. In accordance with Miles et al (1998) these findings suggest that if we define dyslexia according to a clinical criteria and diagnose it accordingly, more males are likely to be found dyslexic than females.

4.3.2 Subtypes versus Severity

The findings of Chapter 3 suggest that severity differences in one or several core deficits provides a more meaningful account of the symptom diversity observed between dyslexics, than attempts to explain this diversity in terms of distinct subtypes. Although these findings are specific to a particular theoretical model and subtyping procedure, and therefore cannot rule out the possibility that dyslexia subtypes may be identified by other means (e.g. clinical subtyping systems or other statistical techniques like factor analysis or cluster analysis), they lend support to the theory that there are no naturally occurring subtypes of dyslexia.

Rather than distinct subtypes, the current findings appear more consistent with the unitary view of dyslexia. Unitary theory maintains that individual differences in dyslexia result from severity differences in a single underlying core deficit, i.e. phonological processing. The current findings could be interpreted as supporting the idea that varying degrees of phonological impairment predict overt literacy skills. The more severe the phonological processing impairment the more severe the reading, spelling and reading comprehension deficits.

Decoding was found to predict the dyslexics' reading ability, which in turn, predicted spelling and reading comprehension. The possibility that phonological processing deficits could detriment spelling and reading comprehension indirectly through reading was discussed in Chapter 3. For example, individuals who experience reading difficulties, possibly as a result of their poor decoding skills, are less likely to

264

engage in reading to the same extent as proficient readers. It is through exposure to print that individuals acquire the orthographic information required for spelling. Poor readers are also less likely to provide accurate and/or complete information to the spelling system.

Poor decoding skills that result in inaccurate reading could also interfere with the ability to comprehend text; i.e. if text is misread it is unlikely that it will be interpreted correctly. As well as resulting in inaccurate word recognition, poor decoding skills could also result in inefficient reading. In this instance, decoding deficits could interfere with the ability to extract meaning from text by over utilising either processing or attentional resources that would otherwise be applied to comprehension. In other words, the effort and attention required for decoding the text detracts from comprehension. The finding that a measure of processing speed predicted a significant amount of the variance in dyslexics reading comprehension could potentially support this efficiency hypothesis. Several possibilities relating to processing efficiency within working memory were discussed in Chapter 3. For example, impaired functioning of the central executive could affect elaborative processing (e.g. connecting information from different parts of the text and making inferences) and/or the ability to compensate for deficient lower-level processes (e.g. a problem with the phonological loop). Either could potentially affect reading comprehension.

In addition to phonological processing, orthographic processing also appeared to be related to the dyslexics' overt literacy skills. For example, performance on the orthographic choice task (OCT) predicted the dyslexics spelling ability. There are several potential mechanisms that could result in dyslexics experiencing problems with orthographic processing. Firstly, it is possible that dyslexics have orthographic processing deficits that are independent of their phonological problems, i.e. caused by a different neurological impairment or visual processing weakness. In this instance, dyslexic symptoms vary as a function of both phonological and orthographic processing. An alternative possibility is that orthographic processing deficits could result from, or be a response to, phonological processing deficits. For example, due to poorly specified phonological representation, the links between

phonology and orthography may be weaker in dyslexics, a factor that could interfere with lexical access. Alternatively, due to their phonological processing deficits, dyslexics could experience reading problems from an early age. Poor readers tend to read less than proficient readers thus restricting their access to print. Lack of exposure to print could result in reduced word knowledge including knowledge of English orthography. As with reading and spelling problems, orthographic processing deficits could be caused by a core phonological impairment.

As predicted by the phonological/surface classification system, dyslexics' symptoms appeared to vary as a function of phonological and orthographic processing. However, on the basis of the current findings it is unlikely that this variability forms two distinct subtypes of dyslexia. In other words, there was no evidence to support the idea that a subgroup of dyslexics will be better at phonological processing than orthographic processing, with another subgroup showing the reverse pattern. The dyslexics within the current study presented as equally impaired on both measures of phonological and orthographic processing. These findings suggest that we can account for more individual variation by examining the degree to which both of these processes are impaired, than by attempting to identify severity differences between these processes.

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267

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Table A.1: Frequency, concreteness, number of syllables and part of speech for each word in List 1.

List 1	Frequency	Concreteness	No. of syllables	Grammatical Structure
Generous	25	260	3	Adjective
Expedition	15	403	4	Noun
Orchestra	60	578	3	Noun
Previous	86	0	3	Adjective
Individual	239	474	5	Adjective
Familiar	72	0	4	Adjective
Gradual	16	0	3	Adjective
Guilty	29	0	2	Adjective
Assist	26	342	2	Verb
Measure	91	366	2	Noun
Attendance	12	0	3	Noun
Endeavour	1	280	3	Noun
Necessary	222	0	4	Noun
Breathe	7	0	1	Verb
Readily	43	0	3	Adverb

Table A.2: Frequency, concreteness, number of syllables and part of speech for each word in List 2.

List 2	Frequency	Concreteness	No. of syllables	Grammatical Structure
Genuine	34	295	3	Adjective
Politician	13	494	4	Noun
Technical	120	0	3	Noun
Various	201	0	3	Adjective
Enthusiastic	24	0	5	Adjective
Immediate	81	0	4	Adjective
Accomplished	44	0	3	Adjective
Liquid	48	555	2	Adjective
Circus	7	535	2	Noun
Welfare	53	309	2	Noun
Description	54	341	3	Noun
Influence	132	280	3	Verb
Television	50	0	4	Noun
Guess	56	247	1	Verb
Equally	62	0	3	Adverb

Table A.3: Mean (standard deviation in brackets) frequency, concreteness and number of syllables for each word in List 1 and 2. Statistical comparisons (independent samples t test) also displayed, as is summary data regarding part of speech.

	List 1 (N=15)	List 2 (N=15)	t-test (df=28)
Frequency	62.39 (73.74)	65.27 (50.91)	-0.101 (p=0.920)
Concreteness	180.20 (212.30)	203.73 (216.11)	-0.301 (p=0.766)
Number of syllables	3.0 (1.0)	3.0 (1.0)	0 (p=1.000)
Adjectives	6	6	-
Nouns	6	6	-
Verbs	2	2	-
Adverbs	1	1	-

Appendix B
Order of task presentation for the adult subjects in section 3.1.

Revised Adult Dyslexia Checklist
University of Hull Student Assessment Information Sheet
WRAT Single Word Reading
WRAT Spelling
NFER Reading Comprehension Test
WAIS-R Vocabulary
WAIS-R Digit Span
WAIS-R Picture Completion
WAIS-R Block Design
WAIS-R Digit Symbol
Complex Non-word reading Task
Castles and Coltheart's (1993) Reading Tasks
PhAB Rapid Naming Tasks
PhAB Verbal Fluency Tasks
PhAB Spoonerisms
Orthographic Choice Task

Appendix C

Analyses of covariance comparing the performance of the dyslexic and non-dyslexic adults (section 3.1) with age as a covariate.

Table C.1: Average scores (with standard deviations in brackets) and statistical comparisons (ANCOVA controlling for age) for dyslexics and non-dyslexics on the reading and spelling tasks.

Reading & Spelling Tests	Dyslexic N=43	Non-dyslexic N=28	f (df=68)
Single Word Reading No. correct out of 57	42.37 (4.72)	50.86 (2.97)	47.197 (p<0.001)
Spelling No. correct out of 55	36.00 (6.60)	46.64 (2.64)	46.801 (p<0.001)
Reading Comprehension No. correct out of 35	16.42 (6.16)	26.29 (4.14)	39.549 (p<0.001)
Regular Word Reading No. correct out of 30	28.33 (2.22)	29.93 (0.26)	7.829 (p=0.007)
Regular Word Reading Speed Time in seconds.	24.43 (16.85)	12.57 (2.04)	7.653 (p=0.007)
Irregular Word Reading No. correct out of 30	23.14 (4.67)	28.32 (1.54)	17.489 (p<0.001)
Irregular Word Reading Speed Time in seconds.	35.12 (25.58)	16.39 (3.61)	6.994 (p=0.010)
Non-word Reading No. correct out of 30	19.53 (6.07)	27.32 (2.86)	34.595 (p<0.001)
Non-word Reading Speed Time in seconds.	50.21 (30.89)	20.89 (5.18)	19.111 (p<0.001)
Complex Non-word Reading No. correct out of 26	16.37 (4.30)	22.11 (2.51)	28.995 (p<0.001)

Table C.2: Average scores (with standard deviations in brackets) and statistical comparisons (ANCOVA controlling for age) for dyslexics and non-dyslexics on the PhAB subtests.

PhAB Subtests	Dyslexic N=43	Non-dyslexic N=28	f (df=68)
Spoonerisms Accuracy No. correct out of 40	27.47 (8.99)	35.93 (3.63)	19.787 (p<0.001)
Spoonerisms Speed Time in seconds	306.44 (140.01)	139.71 (40.28)	31.680 (p<0.001)
Semantic Fluency No. of words generated	15.03 (3.56)	20.44 (4.45)	25.483 (p<0.001)
Alliteration Fluency No. of words generated	8.13 (2.45)	11.34 (3.12)	15.635 (p<0.001)
Rhyme Fluency No. of words generated	6.47 (2.52)	9.45 (2.78)	15.643 (p<0.001)
Picture Naming Time in seconds	38.48 (8.22)	29.38 (3.19)	24.444 (p<0.001)
Digit Naming Time in seconds	22.89 (6.44)	14.88 (3.28)	24.712 (p<0.001)

Table C.3: Average scores (with standard deviations in brackets) and statistical comparisons (ANCOVA controlling for age) for dyslexics and non-dyslexics on the Orthographic Choice Task.

Orthographic Choice Task	Dyslexic N=43	Non-dyslexic N=28	f (df=68)
OCT Accuracy No correct out of 52	46.58 (6.36)	51.79 (0.42)	10.147 (p=0.002)
OCT Speed Time in seconds	103.65 (79.47)	51.04 (9.00)	9.415 (p=0.003)

Box plots showing the performance of dyslexic and non-dyslexic adults (section 3.1) on reading comprehension, regular, irregular and non-word reading, spoonerisms, verbal fluency, rapid naming and the orthographic choice task.

Graph D.1: Reading comprehension scores for dyslexics and non-dyslexics (out of a maximum of 35). The median is indicated by the thick central line, the grey box represents the range within which most individuals scored. The thin lines with a cross line indicate extreme scores and the circles and crosses represent potential outliers.
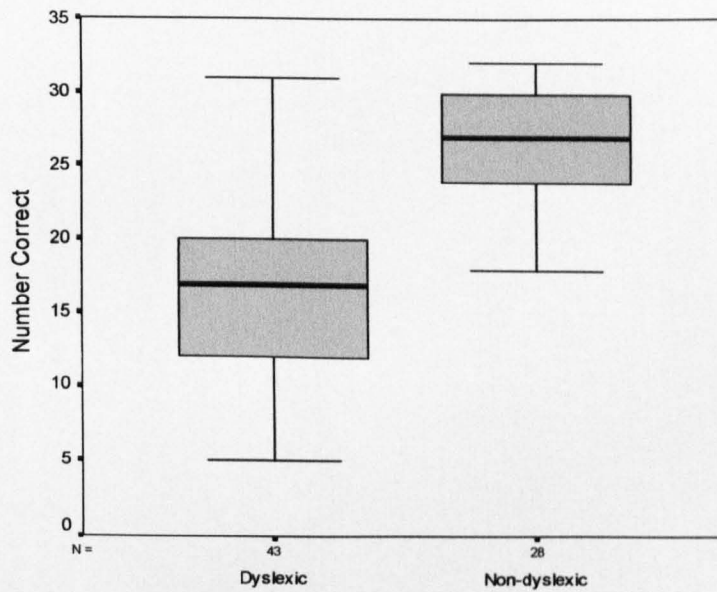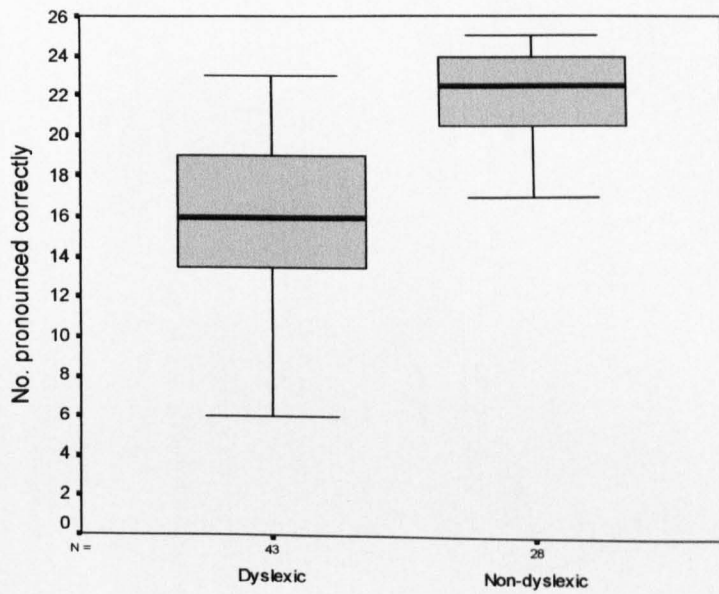
Graph D.2: Regular word reading accuracy scores for dyslexics and non-dyslexics (out of a maximum of 30). The median is indicated by the thick central line, the grey box represents the range within which most individuals scored. The thin lines with a cross line indicate extreme scores and the circles and crosses represent potential outliers.
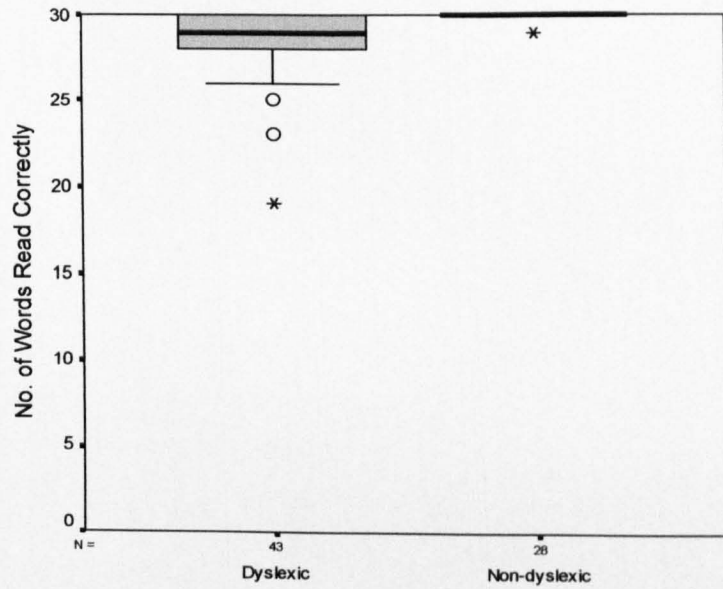
Graph D.3: Regular word reading speed (in seconds) for dyslexics and non-dyslexics. The median is indicated by the thick central line, the grey box represents the range within which most individuals scored. The thin lines with a cross line indicate extreme scores and the circles and crosses represent potential outliers.
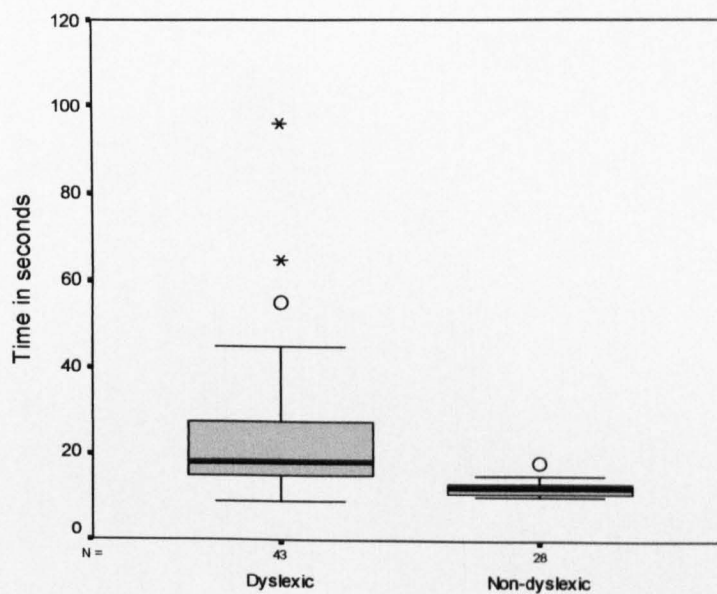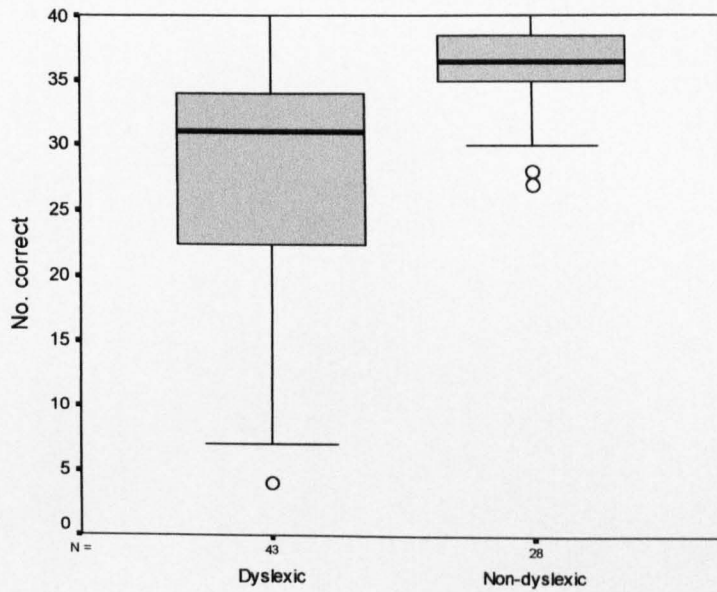
Graph D.4: Irregular word reading accuracy scores for dyslexics and non-dyslexics (out of a maximum of 30). The median is indicated by the thick central line, the grey box represents the range within which most individuals scored. The thin lines with a cross line indicate extreme scores and the circles and crosses represent potential outliers.
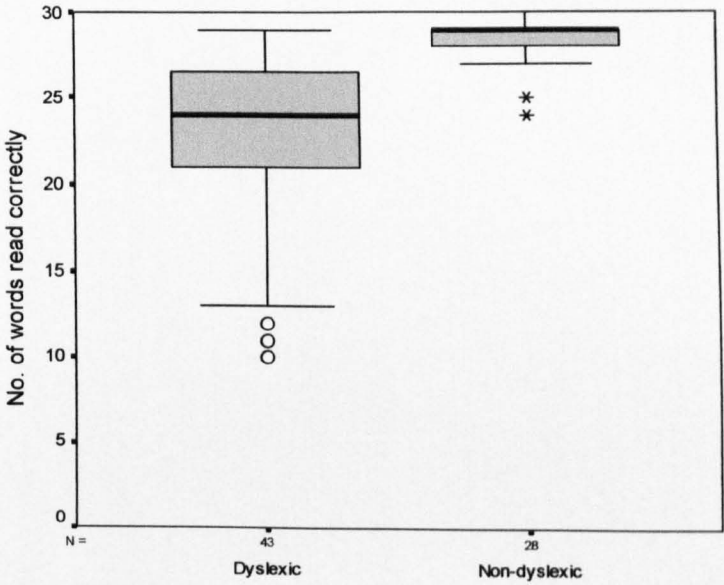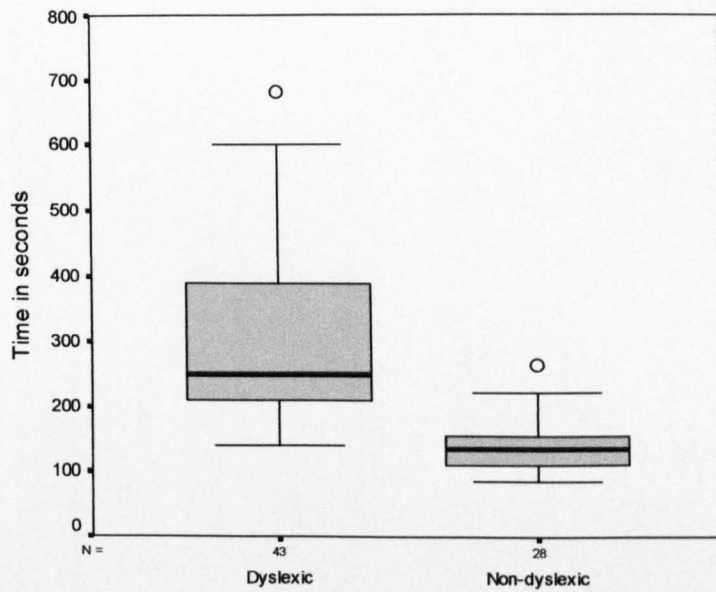
Graph D.5: Irregular word reading speed (in seconds) for dyslexics and non-dyslexics. The median is indicated by the thick central line, the grey box represents the range within which most individuals scored. The thin lines with a cross line indicate extreme scores and the circles and crosses represent potential outliers.
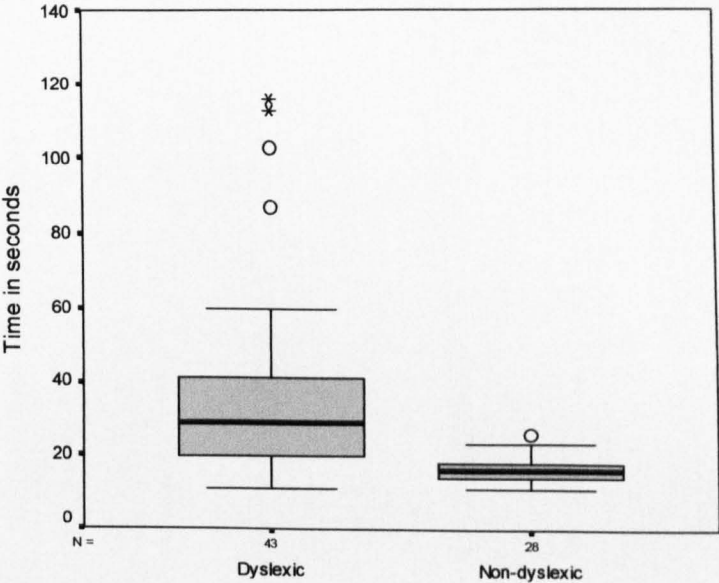
Graph D.6: Non-word reading accuracy scores for dyslexics and non-dyslexics (out of a maximum of 30). The median is indicated by the thick central line, the grey box represents the range within which most individuals scored. The thin lines with a cross line indicate extreme scores and the circles and crosses represent potential outliers.
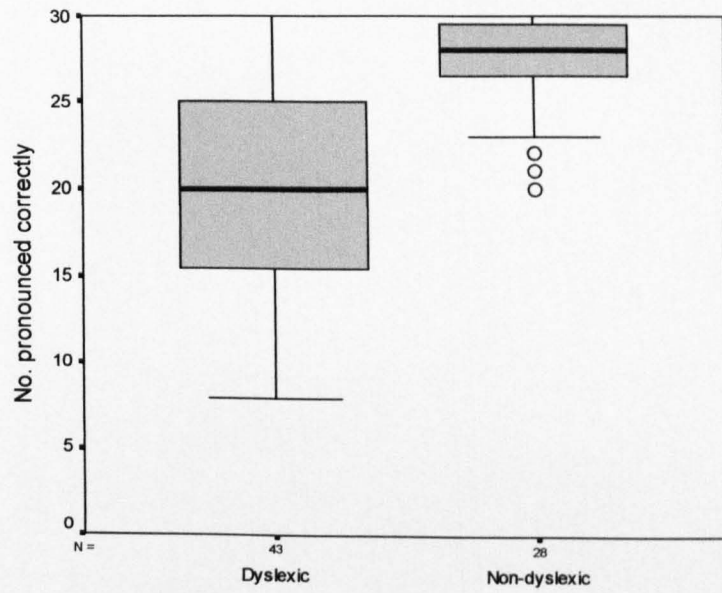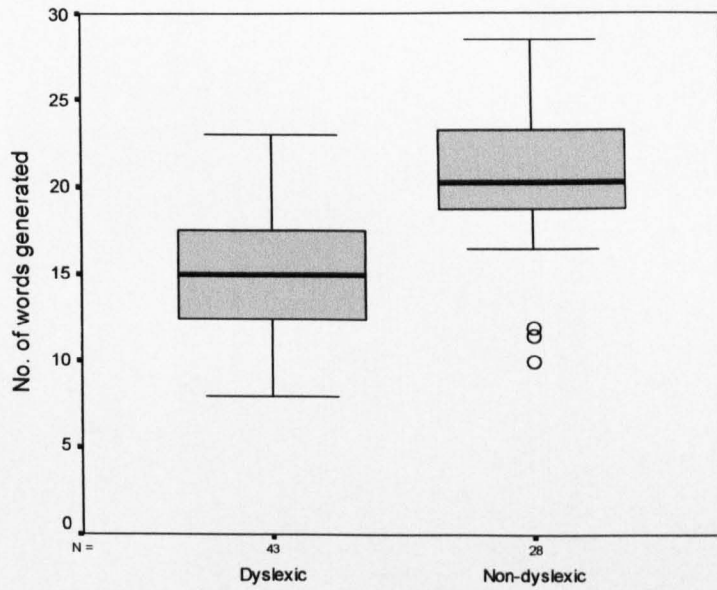
Graph D.7: Non-word reading speed (in seconds) for dyslexics and non-dyslexics. The median is indicated by the thick central line, the grey box represents the range within which most individuals scored. The thin lines with a cross line indicate extreme scores and the circles and crosses represent potential outliers.
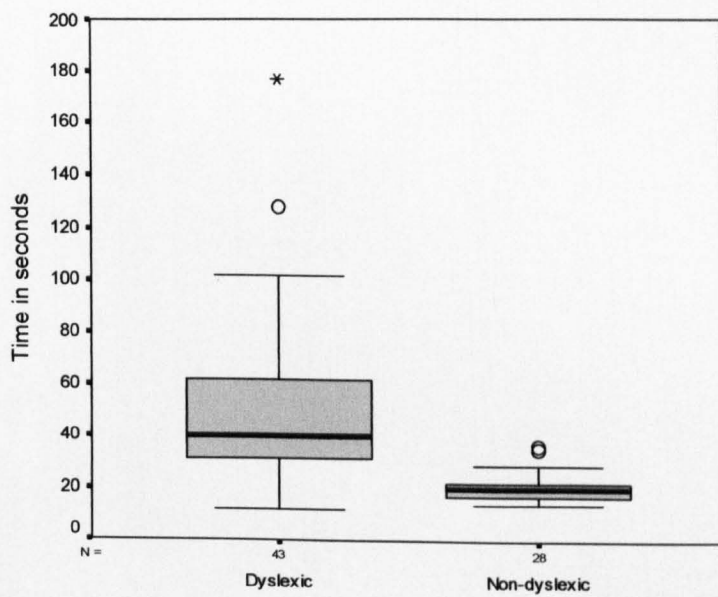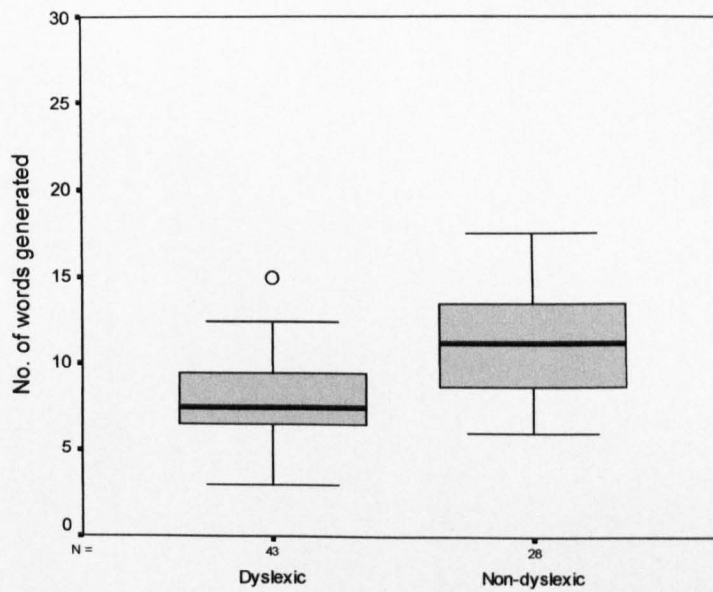
Graph D.8: Complex non-word reading accuracy scores for dyslexics and non-dyslexics (out of a maximum of 26). The median is indicated by the thick central line, the grey box represents the range within which most individuals scored. The thin lines with a cross line indicate extreme scores and the circles and crosses represent potential outliers.

Graph D.9: Spoonerisms accuracy scores for dyslexics and non-dyslexics (out of a maximum of 40). The median is indicated by the thick central line, the grey box represents the range within which most individuals scored. The thin lines with a cross line indicate extreme scores and the circles and crosses represent potential outliers.
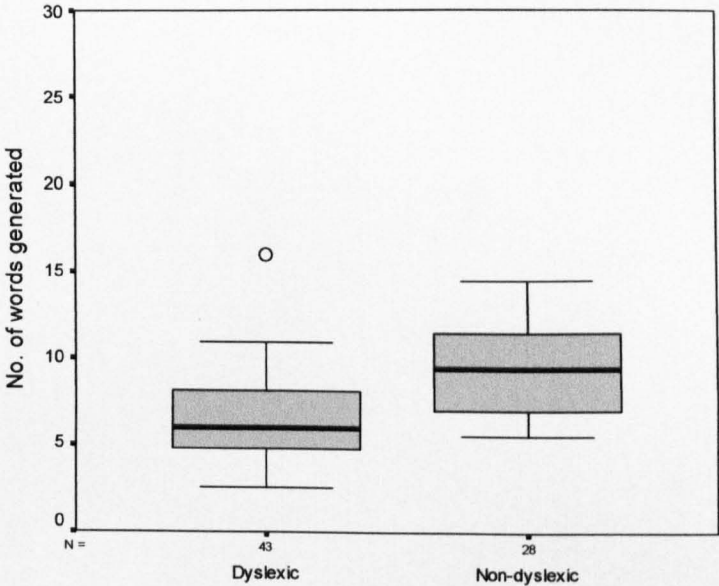
Graph D.10: Time taken to complete the spoonerisms task (in seconds) for dyslexics and non-dyslexics. The median is indicated by the thick central line, the grey box represents the range within which most individuals scored. The thin lines with a cross line indicate extreme scores and the circles and crosses represent potential outliers.
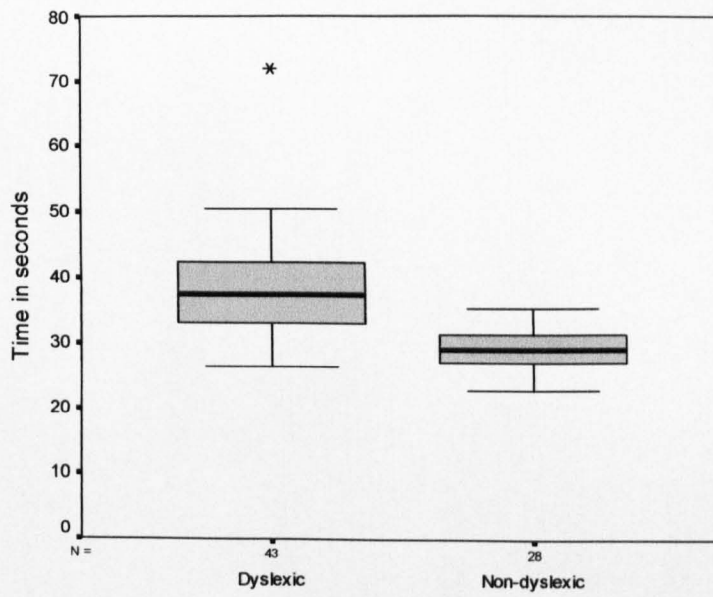
Graph D.11: Number of word generated in 30 seconds on the semantic fluency task by dyslexics and non-dyslexics. The median is indicated by the thick central line, the grey box represents the range within which most individuals scored. The thin lines with a cross line indicate extreme scores and the circles and crosses represent potential outliers.

Graph D.12: Number of word generated in 30 seconds on the alliteration fluency task by dyslexics and non-dyslexics. The median is indicated by the thick central line, the grey box represents the range within which most individuals scored. The thin lines with a cross line indicate extreme scores and the circles and crosses represent potential outliers.
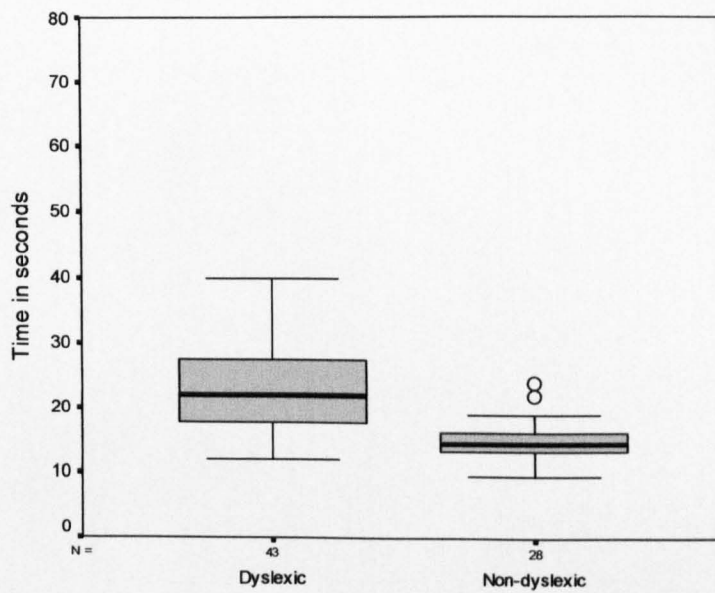
Graph D.13: Number of word generated in 30 seconds on the rhyme fluency task by dyslexics and non-dyslexics. The median is indicated by the thick central line, the grey box represents the range within which most individuals scored. The thin lines with a cross line indicate extreme scores and the circles and crosses represent potential outliers.
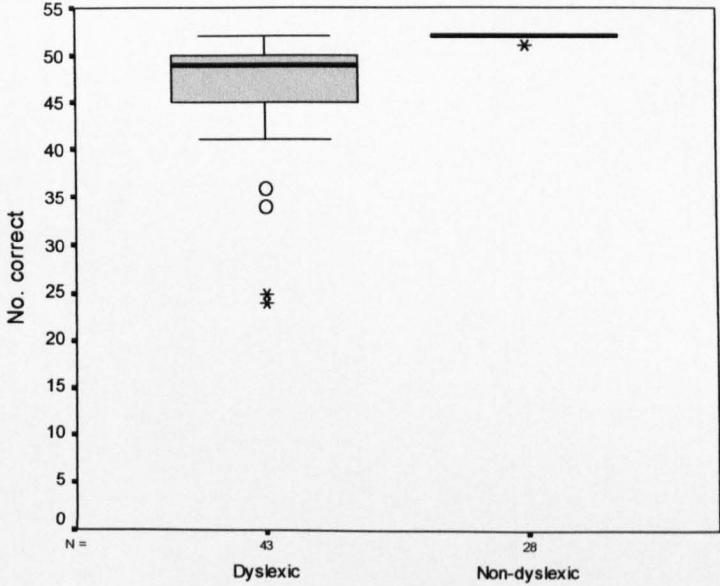
Graph D.14: Picture naming speed (in seconds) for dyslexics and non-dyslexics. The median is indicated by the thick central line, the grey box represents the range within which most individuals scored. The thin lines with a cross line indicate extreme scores and the circles and crosses represent potential outliers.

Graph D.15: Digit naming speed (in seconds) for dyslexics and non-dyslexics. The median is indicated by the thick central line, the grey box represents the range within which most individuals scored. The thin lines with a cross line indicate extreme scores and the circles and crosses represent potential outliers.

Graph D.16: Orthographic Choice Task accuracy scores for dyslexics and non-dyslexics (out of a maximum of 52). The median is indicated by the thick central line, the grey box represents the range within which most individuals scored. The thin lines with a cross line indicate extreme scores and the circles and crosses represent potential outliers.

Graph D.17: Time taken to complete the Orthographic Choice task (in seconds) for dyslexics and non-dyslexics. The median is indicated by the thick central line, the grey box represents the range within which most individuals scored. The thin lines with a cross line indicate extreme scores and the circles and crosses represent potential outliers.
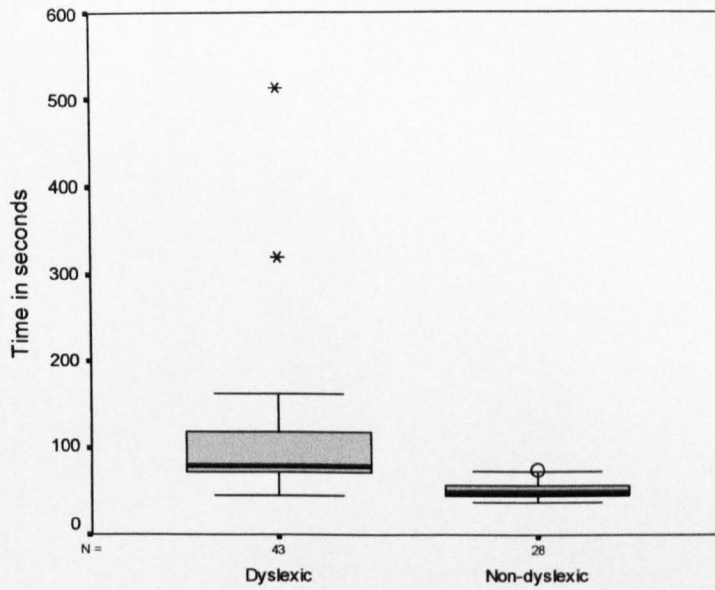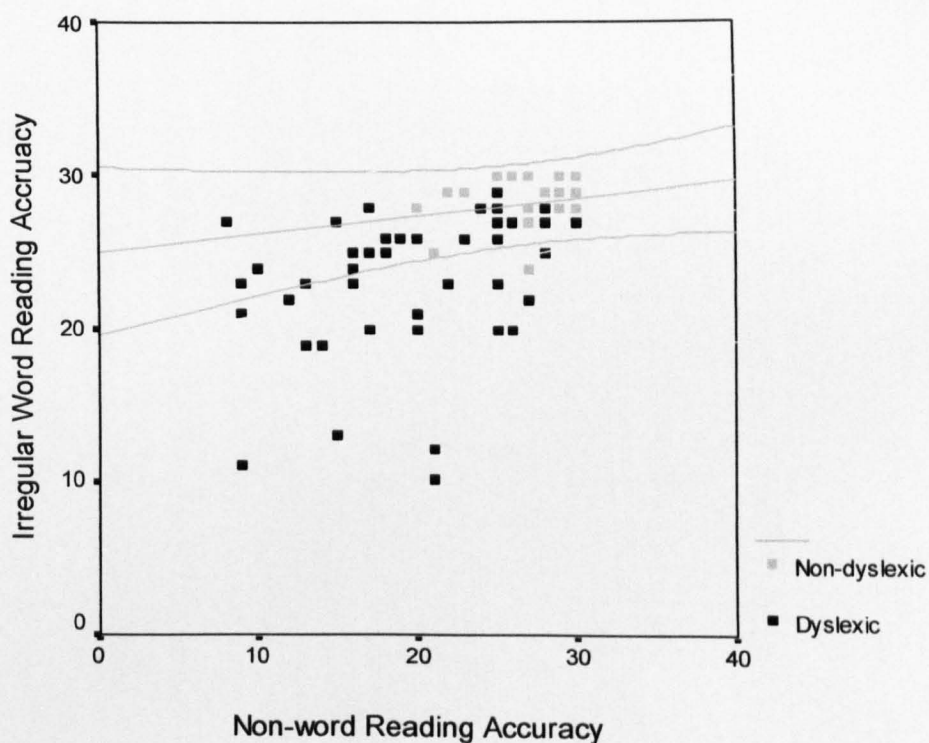
Appendix E

Classification of phonological and surface dyslexics by the standard and efficiency procedure.

Graph E.1: In order to establish which individuals within the dyslexic sample could be classified as surface dyslexics by Castles and Coltheart's (1993) standard procedure, the number of non-words words read correctly by the non-dyslexic's was used to predict irregular word reading accuracy. Upper and lower confidence limits were determined beyond which only 10% of the non-dyslexic scores would be expected to fall. The dyslexics' scores were then imposed on the graph, with those falling below the lower 10% confidence interval being classified as surface dyslexics.

Graph E.2: In order to establish which individuals within the dyslexic sample could be classified as phonological dyslexics by Castles and Coltheart's (1993) standard procedure, the number of irregular words read correctly by the non-dyslexic's was used to predict non-word reading accuracy. Upper and lower confidence limits were determined beyond which only 10% of the non-dyslexic scores would be expected to fall. The dyslexics' scores were then imposed on the graph, with those falling below the lower 10% confidence interval being classified as phonological dyslexics.

Irregular Word Reading Accuracy

Graph E.3: In order to establish which individuals within the dyslexic sample could be classified as surface dyslexics by the efficiency criteria, the time taken by the non-dyslexics to read a list of non-words was used to predict irregular word reading speed. Upper and lower confidence limits were determined beyond which only 10% of the non-dyslexic scores would be expected to fall. The dyslexics' scores were then imposed on the graph, with those falling above the upper 10% confidence interval being classified as surface dyslexics.
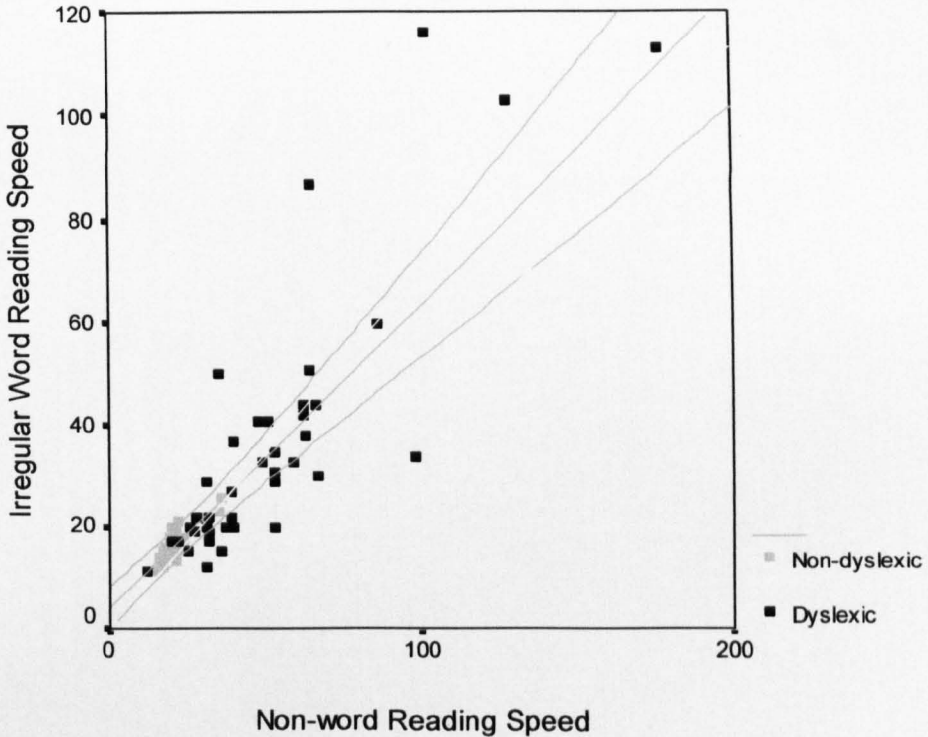
Graph E.4: In order to establish which individuals within the dyslexic sample could be classified as phonological dyslexics by the efficiency criteria, the time taken by the non-dyslexics to read a list of irregular words was used to predict non-word reading speed. Upper and lower confidence limits were determined beyond which only 10% of the non-dyslexic scores would be expected to fall. The dyslexics' scores were then imposed on the graph, with those falling above the upper 10% confidence interval being classified as phonological dyslexics.