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Research into dyslexia provision in Wales

Literature review on the state of research for children with dyslexia

Research

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Audience Local authorities and schools.

Overview The Welsh Government commissioned a literature review, auditing and benchmarking exercise to respond to the recommendations of the former Enterprise and Learning Committee's *Follow-up report on Support for People with Dyslexia in Wales* (2009).

This work was conducted by a working group, which comprised of experts in the field of specific learning difficulties (SpLD) in Wales including the Centre for Child Development at Swansea University, the Miles Dyslexia Centre at Bangor University, the Dyscovery Centre at the University of Wales, Newport, the Wrexham NHS Trust and representatives from the National Association of Principal Educational Psychologists (NAPEP) and the Association of Directors of Education in Wales (ADEW).

Action required None – for information only.

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Related documents *Current literacy and dyslexia provision in Wales: A report on the benchmarking study* (2012)

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This Literature Review was led and edited by Markéta Caravolas (Senior Lecturer in Psychology and Director of the Miles Dyslexia Centre, Bangor University) in collaboration with Amanda Kirby (Professor of Education and Director of the Dyscovery Centre, Newport University), Angela Fawcett (Professor and Director of the Centre for Child Research, Swansea University), and Kathleen Glendenning (Paediatric Physiotherapist and Service Manager for Children with Disabilities, BCUHB - North Wales NHS Trust).

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I. INTRODUCTION

The present literature review was commissioned by Jane Hutt, Welsh Assembly Minister for Children, Education, Lifelong Learning and Skills, in response to the Enterprise and Learning Committee's report "Support for People with Dyslexia in Wales" (2008) and the recommendations therein. The literature review is to guide the Minister (now Leighton Andrews) in the implementation of measures to promote best practice in schools for the support of pupils with dyslexia and other related developmental disorders. The literature review also provides a timely document to inform the newly established National Literacy Plan.

The Enterprise and Learning Committee's report highlighted ten key recommendations for the betterment of support for dyslexic pupils in Welsh schools, including the agreement of a *definition of dyslexia*, *effective early identification* (screening and assessment), *effective intervention* – especially in early years, *teacher training* on dyslexia, and *provision in the Welsh language*. This Literature Review was commissioned as part of the Minister's response to these recommendations, with a view to informing policy decisions about the design and implementation of such provision. The Review is therefore necessarily very broad in its scope, yet our objective was to capture succinctly both the seminal findings in each relevant research area, as well as to summarize the important new findings that are shaping current understanding and developments in dyslexia research and practice. The Review was undertaken with the Welsh context in mind, with attention to advances in dyslexia within bilingual learning settings.

The Review consists of two main documents: (1) the Literature Review, which includes the references and appended Tables, and (2) an Annotated Bibliography. The first document, the Review, is presented in 11 chapters which include the Introduction (Ch. I); an overview of current definitions of dyslexia (Ch. II); an overview of the main theoretical and empirical accounts of the causes of dyslexia (Ch.III); an overview of current knowledge of the manifestation of dyslexia in different languages and in bilingual individuals (Ch. IV); a review of research into developmental disorders that may co-occur with dyslexia (Ch. V); a review of the longer-term educational and psychosocial outcomes of individuals with dyslexia (Ch. VI); an overview of issues associated with screening (Ch. VII) and assessment (Ch. VIII) of dyslexia; a review of the rationale and effectiveness of literacy intervention approaches currently held to reflect best practice (Ch. IX); and a review of some commercially-available complementary intervention approaches (Ch. X); we conclude with a consideration of the implications for best practice in supporting children with dyslexia and other SpLDs in Welsh schools, and with a note on developing a revised definition of dyslexia (Ch. XI). Throughout the Review, summary boxes are used to highlight key concepts and findings, while more detailed data and materials are presented in the Tables of Appendix A (this document). The Reference section contains all publications cited in the literature review as well as those additionally included in the Annotated Bibliography (accompanying document).

The Annotated Bibliography (Appendix B and C) is provided as a supplementary document, which contains a brief description of all of the research cited in the Literature Review, as well as a sample of additional, representative research publications available in topic areas covered in the Review. The summaries are thematically organized (e.g., Phonological Deficit, Memory Deficit, Cross-linguistic Factors, etc.) and are ranked according to the methodological rigour of the study. The criteria for our ranking system are provided in Appendix B. The summaries are structured systematically and include (a) the full reference, and title of each article, (b) a summary of the design, sample size, and statistical approach, (c) a summary of the key findings, and (d) comments of the reviewer, where relevant. In cases where these annotations were not provided, the published article abstract is provided instead.

II. CURRENT DEFINITIONS OF DYSLEXIA

The definition of dyslexia, its aetiology, and most significant manifestations are updated and revised regularly as the ongoing research effort brings new knowledge and understanding. Because the research is being carried out by researchers in different spheres, including education, psychology, biology, neuroscience, and medicine, the focus of a definition can vary depending on the nature of the organization that generated it.

Below, a selection of current definitions by the most prominent national and international organizations is provided. In addition, in Appendix A, Table A1 contains a summary of the key similarities and differences among definitions of 11 organizations and specialist bodies. The table allows the reader to see the best established findings to date on the behavioural markers of dyslexia.

II.i Definitions of Key UK Bodies

British Dyslexia Association (17 October, 2007)
Dyslexia is a specific learning difficulty, which mainly affects the development of literacy and language related skills. It is likely to be present at birth and to be life-long in its effects. It is characterised by difficulties with phonological processing, rapid naming, working memory, processing speed, and the automatic development of skills that may not match up to an individual's other cognitive abilities. It tends to be resistant to conventional teaching methods, but its effects can be mitigated by appropriately specific intervention, including the application of information technology and supportive counselling.

Department for Education and Skills (2004)
We understand dyslexia to be a *specific difficulty*, typically characterised by an unusual balance of skills. Dyslexia affects information processing (receiving, holding, retrieving and structuring information) and the speed of processing information. It therefore has an impact on skills such as reading, writing, using symbols and carrying out calculations. However, there are many differing definitions; dyslexia is an umbrella term. It is important to recognise that:

- dyslexia is not related to intelligence and can occur in severe, moderate, or mild forms
- people with dyslexia have their own individual profiles of strengths and weaknesses; no two people are exactly the same and the impact of dyslexia on each individual is different
- dyslexia does not only affect literacy skills such as spelling, but most of what we know about it relates to its relationship to language and literacy
- dyslexia may overlap with related conditions such as dyspraxia, attention deficit disorder (with or without hyperactivity) and dysphasia
- most people appear to be born with dyslexia, although others acquire it through accident or illness
- many people with dyslexia have a family member with the same condition
- some researchers think that dyslexia affects more men than women; others think that roughly the same numbers of males as females are affected.

Rose Dyslexia Review 2009
Dyslexia is a learning difficulty that primarily affects the skills involved in accurate and fluent word reading and spelling.

Characteristic features of dyslexia are:

- Difficulties in phonological awareness, verbal memory and verbal processing speed.
- Dyslexia occurs across the range of intellectual abilities.
- It is best thought of as a continuum, not a distinct category, and there are no clear cut-off points.
- Co-occurring difficulties may be seen in: aspects of language, motor co-ordination, mental calculation, concentration and personal organisation, but these are not, by themselves, markers of dyslexia.

A good indication of the severity and persistence of dyslexic difficulties can be gained by examining how the individual responds or has responded to well-founded intervention.

Dyslexia Scotland (Definition produced by the Scottish Government in collaboration with a range of stakeholders including *Dyslexia Scotland*)

Dyslexia can be described as a continuum of difficulties in learning to read, write and/or spell, which persist despite the provision of appropriate learning opportunities that are effective for the majority of learners. These difficulties may not be typical of an individual's performance in other areas.

Ranging from mild to severe, there may be associated difficulties in areas such as:

- auditory and /or visual processing of language-based information;
- phonological awareness;
- oral language skills;
- short-term and working memory;
- sequencing;
- number skills;
- organisational ability.

Motor skills and co-ordination may also be affected. Dyslexia exists in all cultures and across the range of abilities and socio-economic backgrounds. It is a life-long condition which is generally considered to be hereditary.

II.ii Definitions of Key International Bodies

International Dyslexia Association (IDA)
Dyslexia is a specific learning disability that is neurological in origin. It is characterized by difficulties with accurate and/or fluent word recognition and by poor spelling and decoding abilities. These difficulties typically result from a deficit in the phonological component of language that is often unexpected in relation to other cognitive abilities and the provision of effective classroom instruction. Secondary consequences may include problems in reading comprehension and reduced reading experience that can impede the growth of vocabulary and background knowledge. (Adopted by the Board of Directors: November 12, 2002.)

Diagnostic and Statistical Manual of Mental Disorder Fourth Edition Text Revision 2005 (DSM-IV-TR)
Reading Disorder -- Diagnostic Features*.* The essential feature of Reading Disorder is reading achievement (i.e., reading accuracy, speed, or comprehension as measured by individually administered standardized tests) that falls substantially below that expected given the individual's chronological age, measured intelligence, and age-appropriate education.

- *Criterion A.* The disturbance in reading significantly interferes with academic achievement or with activities of daily living that require reading skills.
- *Criterion B.* If a sensory deficit is present, the reading difficulties are in excess of those usually associated with it.
- *Criterion C.* If a neurological or other general medical condition or sensory deficit is present, it should be coded on Axis III.

In individuals with Reading Disorder (which has been called "dyslexia"), oral reading is characterized by distortions, substitutions, or omissions, both oral and silent reading are characterized by slowness and errors in comprehension.

Associated Features and Disorders. Mathematics Disorder and Disorder of Written Expression are commonly associated with Reading Disorder, and it is relatively rare for either of these disorders to be found in the absence of Reading Disorder.

Overview of Dyslexia Definitions

The majority of the definitions highlighted the fact that dyslexia is a specific learning difficulty that affects literacy skills. The definitions are mainly descriptive and causation is not addressed. However, where causation is stated it is believed to be neurological in origin. A variety of deficits associated with the disorder is highlighted, the most common of which include literacy difficulties and phonological impairments, and these may range from mild to severe and are unique to each individual. The disorder is life-long, however its effects may be mitigated through the use of appropriate teaching methods. The main discrepancies between definitions involve inclusion of some of the behavioural manifestations of the disorder, in particular motor skills and coordination deficits and whether intellectual abilities can be used for diagnosis.

Issues and New/Future Directions in Defining Dyslexia

The discrepancy definition of dyslexia is being replaced by a dimensional definition with a core deficit in phonological processes (Bishop, Snowling, & Blakemore, 2008). The BPS definition focuses on a descriptive and not a causal explanation of dyslexia. Dyslexia is increasingly seen as a disorder that may include more than one domain of impairment. For example, dyslexia may result from not only a phonological deficit but also other co-occurring deficits in areas such as general language or visual attention. Importantly, the balance of current evidence indicates that none of the deficits frequently seen to co-occur with the phonological deficit is sufficient to cause the disorder on its own.

Future research will need to establish the prevalence of 'pure' phonological dyslexia, relative to 'dyslexia with comorbid or co-occurring deficits', and to define clearly which additional symptoms are directly causal in dyslexia, and which coexist, and compound the dyslexic difficulties through indirect effects.

III. MAIN THEORETICAL ACCOUNTS AND ASSOCIATED EVIDENCE

Overview

Dyslexia can be studied from many different perspectives, and there has been no shortage of theoretical proposals to explain the condition of dyslexia over the past century. In the sections that follow, we summarize the theories that have attracted considerable attention from researchers and we present some representative research investigating the particular theories. More detailed summaries of the literature are provided in the Annotated Bibliography, annexed to the present document (Appendix C). The research summaries in the Annotated Bibliography are ranked in terms of their methodological strength, and we provide a description of these criteria in the Appendix B. Although we do not adopt one particular theoretical perspective in the present review, we have attempted to select the papers that have met the most rigorous standards of scientific inquiry to represent each view. This said, the research base is not equally advanced for every theory; in cases where no consensus has yet been reached, and/or where the critical research has yet to be carried out, we report research that reflects the current debate in the field.

III.i Cognitive and Brain Bases of Dyslexia

Recent research and research currently in progress

The theories are presented in the order in which they have emerged, with examples of interesting recent research within each framework. There have been striking developments in dyslexia research in the last fifteen years, with various theories hoping to fill in part of the jigsaw that might explain the complex problem of dyslexia, which can extend beyond literacy difficulties and impact on an individual throughout his/her life. The UK is at the forefront in this theoretical research, and an aspiration of the scientific community is to advance both the theoretical and empirical work so as to develop a comprehensive explanation of the causes and manifestations of dyslexia. In organizing this literature review, an important distinction between the three 'levels' of theory proposed by Frith (1997) was considered: the *biological*, the *cognitive* and the *behavioural* levels.

1. The behavioural level examines the symptoms of dyslexia, such as poor reading, or phonological awareness deficits, and verbal memory difficulties.
2. At the cognitive level, theories propose to account for the causes of dyslexics' observable difficulties on the basis of hypotheses about structural or functional differences in the brain's information processing capacities. For example, different theorists have proposed that dyslexics' pervasive reading and spelling deficits are caused by underlying problems in cognitive domains such as phonological processing, visual attention, skill automatisation, and slow processing speed.
3. Finally, at the biological (i.e., brain and/or genetic) level lie the underlying brain mechanisms and the potential determinants of their development. Differences between the brains of dyslexic and nondyslexic individuals have been investigated in parts of the brain, including language areas, the frontal lobes, magnocellular pathways, and the cerebellum. Work is under way in behavioural genetics to identify the genes that may play a role in determining these brain and behavioural differences.

It has been recognised that any complete explanation of dyslexia must include all three levels, with the cognitive level providing a necessary link between the brain and behaviour. In the ensuing sections, we highlight the links between these three levels of investigation and explanation wherever possible.

Phonological deficit: theory and evidence

The phonological deficit theory is the best developed and supported of the theories of dyslexia. Its basic premise is that the difficulties manifested in dyslexia (especially those related to reading and spelling) are caused, wholly or in part, by difficulties in the speech-sound (or phonological) system of language. This theory has been widely researched, in the UK, the US, and in numerous other countries. Many US researchers have investigated the phonological deficit hypothesis since the early 1980's, and this has led to the investment of more than $15 million annually by the US government, via the National Institute for Child Health and Human Development (NICHD).

There is unanimous agreement that problems with *phonological processing* are associated with dyslexia. Phonological processing is assessed by a variety of tests related to the abilities to perceive, produce, manipulate, analyse and remember the sounds of spoken language. A widely used approach to assessing phonological processing, especially in children, is the use of *phonological awareness* tasks. These include skills such as breaking down words into their sound parts, or making judgments about them. For example, knowing that 'cat' can be divided into its 'onset' consonant /k/ and 'rime' unit /at/, and that in turn, its individual sounds (phonemes) are /k/-/æ/-/t/, or, judging that 'cat' rhymes with 'mat', are all demonstrations of phonological awareness. Although awareness can occur at various levels, such as the syllable, the onset and rime, it is awareness of individual *phonemes* (speech sounds) that is the skill most critically related to emergent literacy (Byrne, 1998; Hulme et al., 2002).

Phoneme awareness helps children to learn the connections between alphabet letters and their sounds and these skills need to develop by the time children begin to learn to read alphabetic orthographies, like Welsh and English, if they are to learn successfully. Children who cannot learn these connections effectively are limited in the strategies that they can use to read words; for example, they may need to rely on memorizing printed words as wholes, or on guessing, and of course this would seriously limit their ability to learn to read new words autonomously (Share, 1999; Byrne, 1998; Hatcher, Hulme, & Ellis, 1994). There is solid evidence dating from the seminal work of Bradley and Bryant (1983), that phonological awareness, as well as a variety of other phonological processing skills, including rapid pronunciation of words, the repetition of nonsense words, and verbal short term memory are impaired in children with dyslexia and the impairments persist into adulthood. For recent reviews of the area see Hulme and Snowling (2009), Vellutino, Fletcher, Snowling, and Scanlon (2004).

Some of the most informative studies fall into 3 groups:

- Predicting which children from a population 'at genetic risk' are likely to develop dyslexia.
- Longitudinal studies on outcomes for individuals with childhood disorders related to literacy.
- Intervention studies assessing teaching approaches to ameliorate literacy difficulties (these are reviewed in Chapter IX – on intervention).

These types of studies provide evidence that the efficiency of phonological processing is crucial to literacy development. In addition, however, recent studies recognize that dyslexia frequently presents as a complex disorder, and some additional important predictors of progress have been investigated.

a) *Studies of 'at risk' populations*. These studies have examined pre-school children with a family history of dyslexia for early indications of dyslexia (Gallagher et al., 2000; Pennington & Lefly, 2001; Scarborough, 1990). There is strong genetic evidence that children who have a parent(s) with dyslexia have a 50% chance of having difficulties themselves (see Fisher et al, 2001, and the section on III.ii below), so this is an important group to target in order to find out more about pre-school development and about their longer-term outcomes. In a series of studies by Snowling and colleagues, a cohort of children at risk of dyslexia was followed from the age of 45 months until 13 years. The researchers found that letter recognition of 45-month-olds proved the best predictor of literacy attainment at 6 years; moreover, those children who were already showing a literacy delay at age 6 had also experienced delays in all aspects of language development (Gallagher et al, 2001). Follow-ups at age 8, and again at age 13 (Snowling, Gallagher & Frith, 2003; Snowling, Muter, & Carroll, 2007; Muter & Snowling, 2009) indicated that family risk was continuous. Those who had shown literacy delays already in early childhood went on to have serious literacy, phonological, and oral language difficulties in later childhood and adolescence, and, even those 'at risk' children who had shown no *major* reading difficulties in the early school years, went on to experience subtle but significant difficulties in the areas of spelling, phonological processing and fluency in later development. In contrast, a protective factor that moderated the severity of children's literacy difficulties was expressive vocabulary and good verbal skills. Long-term predictors of poor outcomes included the presence of co-occurring difficulties (in addition to their phonological difficulties) in areas such as attention, mathematics, fine motor control, and spoken language, although none of these on its own was associated with poor reading. Finally, a finding with strong educational implications was that from 8 to 13 years of age, dyslexic children's reading ability remained stable; there was no evidence of 'catching up' despite continued schooling.

b) *Longitudinal studies contrasting dyslexia and other developmental disorders*. Another way to investigate the cognitive and behavioural markers of dyslexia is through longitudinal studies that follow groups of children who do or do not present with behavioural markers of dyslexia over periods of months and years in order to track their developmental trajectories, and to validate that the behavioural markers indeed specifically predict dyslexic difficulties in later years. In light of findings that dyslexia is a language-based disorder, numerous studies have sought to distinguish between children with early language difficulties (LI) and/or speech sound disorder (SSD), who go on to have dyslexic-type difficulties with word recognition and spelling, and those who go on to have broader language and literacy difficulties, including poor reading comprehension (see Bishop & Snowling, 2004, and Pennington & Bishop, 2009, for a recent review). These studies reveal a complex picture of the causes and risk factors of dyslexia.

In a representative series of studies by Bishop and colleagues (Bishop & Edmundson, 1987; Bishop & Adams, 1990; Stothard, Snowling, Bishop, Chipchase & Kaplan, 1998; Snowling, Bishop & Stothard, 2000), children who had been identified with language deficits in pre-school were followed up in terms of their literacy outcomes in primary school (age 8), and as teenagers (age 15). Although 65% of the children went on to have reading difficulties, their trajectories differed from typical profiles of 'pure' dyslexics. For example, the LI children's reading skills deteriorated over time, whereas the reading skills of dyslexic children tend to remain weaker but stable over time. Moreover, the LI children went on to develop spelling skills that were relatively stronger than their reading skills, while the opposite pattern is typically found in dyslexia. Also, nonverbal intelligence was found to be the most protective factor against continuing difficulties; this suggests that LI children with good visual and nonverbal reasoning skills might be able to acquire better memory representations for word spellings than those with weak nonverbal skills. Several more recent studies directly contrasting children with dyslexia and those with LI and/or with SSD further suggest that while phonological processing deficits present a risk factor for all three disorders, a protective factor mitigating poor reading outcomes is rapid automatised naming (RAN) ability (see below). Together, these studies show that while there are some overlaps between the cognitive and behavioural markers of LI and dyslexia, the developmental profiles of each disorder also differ from each other in key ways. A series of cross-sectional studies by Ramus and colleagues clearly showed that phonological problems have a higher incidence than any of the other deficits in dyslexia (Ramus, Pidgeon & Frith, 2003; White, Milne et al., 2006). However, the emerging research reveals that the severity of reading problems is frequently compounded by other factors that contribute to the expression of dyslexia in those at risk.

Verbal short-term memory deficit – an aspect of phonological processing. The most consistently observed memory deficits among dyslexics involve verbal short term memory and working memory. Memory deficits refer to difficulty retaining information necessary for performing tasks.

Verbal short term memory

This involves the temporary storage of information. Memory *span* tasks, which require the spoken recall of lists of words or digits, are generally used as measures of short term memory capacity. For example, the Forward Digit Span task, is a part of most test batteries of psycho-educational ability, and it is most widely used to assess this aspect of memory (Nelson & Warrington, 1980).

Working memory

This involves the concurrent storage and processing or manipulation of information (Archibald & Gathercole, 2006). For example, the Backward Digit Span task is often used to assess working memory. The task is similar to the forward digit span, however, it requires that digits are recalled in the reverse order of presentation. It is considered a test of working memory because in addition to storing the digits for recall, the digits also have to be processed/manipulated for presentation in the reverse order.

Summary of Research findings on Memory Deficits

The existence of memory deficits in dyslexia is well established by research (Cohen-Mimran & Sapir 2007; Gathercole, Alloway, Willis, & Adams, 2006; Nelson & Warrington 1980; Schuchardt, Maehler, & Hasselhorn, 2008). Evidence has been reported of deficits in verbal short term memory, working memory, and long term memory (Gathercole et al., 2006; Jorm, 1983; Nelson & Warrington, 1980). As with other markers of dyslexia, some researchers have argued for the existence of a domain general processing deficit among dyslexics, affecting

several areas of memory, while others argued for a domain specific deficit affecting discrete areas such as verbal short term memory (Cohen-Mimran & Sapir 2007). The areas of memory in which deficits are most commonly found are, indeed, *verbal* short term and working memory. For example, in a review of specific reading retardation and working memory deficits, Jorm (1983) reported reduced memory span and poor short term memory for serial order among poor readers. Also Nelson and Warrington (1980) found that dyslexic children had deficits in short term memory and verbal long term memory, while in a more recent study, Gathercole et al. (2006) found, in addition, working memory deficits among children with reading disabilities.

Possible causes of memory deficits identified by research include functional inefficiencies in brain regions such as the inferior parietal lobe and left temporal lobe (Beneventi, Tønnessen, Ersland, & Hugdahl, 2010; Nelson & Warrington 1980). It is suggested that deficits in memory may affect reading acquisition and comprehension due to impairment in the retrieval of phonological information from long term memory and inadequate storage of information about words (Jorm, 1983). The presence of memory deficits associated with dyslexia have implications for both assessment and intervention. Thus, in light of their prevalence, testing for these deficits needs to be included in assessment.

Estimating the Phonological Deficit

Measures of phonological processing

This is the most prevalent feature of dyslexia. The way it is measured varies with age with some tests being better suited for younger children while others are more suitable for adults. While accuracy is the most reliable measure with children, response speed is the most appropriate way to measure phonological abilities in older children and adults. Below is a brief summary of some of the aspects of phonological processing that have been investigated.

Phonological Awareness includes the ability to consciously manipulate and make judgments about units of sound in spoken words and nonwords. Task difficulty can be manipulated to be suitable for younger and older children, and adults.

Phonological fluency requires pronouncing as many words and non-words as possible in a short amount of time. The challenge is to name aloud as many items as possible that share a phonological attribute with a prompt word (e.g., words that share the first/last sound as the prompt). This measure is simple to administer, and suitable for children and adults.

Non-word reading
Testing the accuracy and speed with which non-words (e.g., SMIP, HEFLIN) are read. Along with spelling it is seen as more suitable for identifying phonological deficits in adults, especially these who are well compensated.

Digit Span involves the verbal recall (repeating) of groups of digits of increasing length in the same order of presentation. The more digits recalled, the greater the memory capacity. *Word Span* uses words or non-words for recall instead of digits.

Implications for diagnosis and intervention
It is now strongly recommended that assessment and diagnostic test packages include tasks assessing phonological processing skills.

Is it relevant to Welsh?
Certainly. Phonological awareness deficits have been found to be predictive of reading and spelling outcomes in numerous languages, including Welsh.

Rapid automatised naming (RAN) deficit: Theory and evidence

Rapid automatised naming (RAN) tasks are simple measures of the speed with which a small number (e.g., 5-6) of repeating stimuli, such as depicted objects, numbers, letters or colours, are verbally named. The stimuli are normally presented on a grid of approximately 8 objects on each of 5 rows, and the task is to name each item quickly in serial order. The time taken to complete the task is the critical measure in most versions of RAN. The RAN deficit refers to a slow and effortful performance on these simple naming tasks.

Summary of research findings on the RAN deficit

RAN has proven to be another very important marker of dyslexia and there is strong and consistent evidence of a rapid naming deficit among many (though not all) dyslexic individuals (Denckla & Rudel 1976; Semrud-Clikeman, Guy, Griffin, & Hynd 2000; Wolf, Bowers, & Biddle 2000). RAN speed is a significant predictor of word reading ability and disability in children (Lervåg & Hulme, 2009), and its predictiveness persists into adulthood (Wolf & Bowers, 1999). Research also indicates that in transparent orthographies (e.g., German, Norwegian), the RAN deficit is a stronger long-term predictor of reading difficulties (dyslexia) than are phonological abilities (Lervåg, Bråten, & Hulme, 2009; Wimmer, Mayringer, & Landerl, 2000). RAN is most predictive of attainments in reading fluency (speed) and comprehension.

Given the clear association between RAN and reading ability, a great deal of effort has gone into understanding the nature of this link; however, this has proven surprisingly elusive. The RAN task, although very simple to administer, is in fact quite complex and involves numerous component skills, such as speeded access to the name of the picture/symbol, articulation (in naming aloud), tracking the sequence of pictures/symbols, and sustaining concentration for the whole set of stimuli. It is not clear which component(s) cause(s) the rapid naming deficit. Researchers are currently debating whether it is simply an extension of the phonological deficit, reflecting difficulties such as poor speech encoding, or slow verbal retrieval (e.g., Wagner, Torgesen & Rashotte, 1994). This explanation is not likely to provide a complete explanation, however, because RAN deficits are sometimes found in the absence of phonological problems, and are nevertheless linked to slow reading (Powell, Stainthorp, Stuart, Garwood, & Quinlan, 2007; Wimmer, et al., 2000). Another explanation proposes the RAN deficit to reflect poorly developed connections between visual symbols and verbal labels, including speech sounds and letters (e.g., Lervåg & Hulme, 2009), or a faulty 'timing mechanism' that links phonological and orthographic forms – although the latter mechanism remains ill-defined and unidentified (Wolf & Bowers, 1999; Wimmer, et al., 2000). Others still suggest the key difficulty to be subtle visual-attentional processing delays (Denckla & Rudel, 1976), or differences in strategic control of eye movements, based on differences in reading skill and experience (Clarke, Hulme, & Snowling, 2005). In an eyetracking study, Jones, Obregon, Kelly, & Branigan, (2008) identified both visual and phonological components in RAN but noted that the greatest deficits emerged in components of the task that included naming (i.e., phonological processing). Another view suggests that RAN deficits reflect a domain general processing speed disorder (see also the section on *Processing Speed Deficit* below), which possibly includes phonological, motor and orthographic components (Korhonen, 1995; also see discussion in Pennington & Bishop, 2009). Clearly, although the RAN deficit still awaits a full scientific explanation, it presents an important diagnostic tool for the assessment of dyslexic difficulties and is indicative of slow and effortful reading.

Double Deficit (of phonological processing and naming)

In one of the more recently developed theories, Wolf and Bowers (1999; Wolf, 2001) have brought together the phonological and naming speed problems in the double-deficit hypothesis, which suggests that there are two separate sources of difficulty in dyslexia, phonological processing and naming speed. In fact, according to the proponents of the double-deficit hypothesis, these two deficits present the main cognitive deficits underlying developmental dyslexia. Relative to children who experience only one of the deficits, children with both have the most severe problems. As mentioned in the previous section, recent research has revealed fluent naming (i.e., good RAN performance) to be a protective factor in the light of phonological processing deficits (Bishop, McDonald, Bird, & Hayiou-Thomas, 2009); it remains to be seen whether the reverse also holds true.

The RAN deficit - Educational implications

It is clear to practitioners that accuracy is not enough to make children good readers, and that they need to develop fluency as well. Dyslexic children with RAN deficits need longer to read even those words that are familiar to them (van der Leij & van Daal, 1999), and this may lead to ineffective strategies for word recognition, such as processing large groups of letters in reading, rather than breaking the word down phonologically in order to read unfamiliar words. This approach makes heavy demands on working memory, and limits the new words that can be tackled. Frustratingly, intervention studies aimed at improving naming speed and reading fluency have met with little success, to date (de Jong & Vrielink, 2004; Thaler et al., 2004).

Other Observed Deficits

In the ensuing sections, we present brief descriptions of several other deficits that have been observed and their associated theories. Unlike the Phonological and RAN deficits, the ones described below have a less consistent body of evidence supporting them, although some of the theories are relatively new and therefore await further research. Much of the research summarised below may be better understood in terms of comorbid difficulties (a topic we cover in Chapter V). That is, the less systematic findings may reflect the fact that the conditions described do not define or cause dyslexia, but may co-occur with it and compound its effects in some but not all individuals with dyslexic difficulties.

Processing Speed Deficit: Theory and Evidence

Speed of information processing refers to the rate at which sensory information entering the nervous system can be processed (Bonifacci & Snowling, 2008). A processing speed deficit refers to a deficiency in the rate and the efficiency with which information is processed. Processing speed is usually assessed using reaction time tasks which measure the rate of response to different stimuli.

Summary of research findings on Processing speed deficit

Many studies report dyslexics to be slower on various types of speeded tasks, including those where rapid sensory processing is not needed (Nicolson & Fawcett, 1994b; Miller, Kail, & Leonard, 2001). Additionally, research indicates that this impairment may increase as the task demand increases (Nicolson & Fawcett 1994b). Problems may be found even when language is not involved. For example, Nicolson and Fawcett (1994b) reported that children with dyslexia were slower to simply press a button when choosing between a high and a low tone. In a study which measured the speed of brain waves to see whether the problem lay in registering the tone (sensory) or categorising it as high/low, (using EEG evoked potentials) Fawcett et al., (1993) found slowed central auditory information processing (see recent cerebellar research below). These authors further proposed that the speed impairment may affect either perceptual classification or central decision processes. However, the findings regarding a general processing speed deficit in dyslexia are not unanimous. Some studies have found the performance of dyslexic children (Bonifacci & Snowling, 2008) and adults (Judge, Caravolas, & Knox, 2006; 2007) to be similar to their peers. For example, Judge et al., (2006, 2007) found adults with developmental dyslexia to have no processing speed impairments on non-linguistic tasks, however these same individuals showed serious deficits in speeded phonological awareness tasks. This finding fits with the view that dyslexics have a deficit in speed of processing in the aural, phonological system used for reading (Breznitz, 2001 as cited in Breznitz & Meyler, 2003).

Despite the above differences in experimental findings in groups of dyslexics, processing speed has been found to be a predictor of reading comprehension and word recognition (Catts, Gillispie, Leonard, Kail, & Miller, 2002). As reported earlier, some recent findings suggest that the RAN deficit is but one aspect of a domain general processing speed disorder (Korhonen, 1995; Pennington & Bishop, 2009). To summarise, there is as of yet uncertainty about whether the deficit is domain general (affecting all cognitive processes) or specific to certain modalities (such as visual and auditory processes). However, from a diagnostic point of view, speed of processing skills should be assessed as they may be positive markers of dyslexia.

Executive Function Deficit: Theory and Evidence

Executive function refers to a number of different cognitive abilities such as inhibition (the prevention of a behavioural or verbal response), organization, sequencing, problem solving and planning. Various tasks have been used to assess the different aspects of executive functioning.

Summary of findings on Executive Functioning Deficit

Research on an executive functioning deficit among dyslexics is limited but has provided some insights (Brosnan et al., 2002; Helland & Asbjornsen 2000; Reiter, Tucha, & Lange 2005; Wolf, Sambataro, Lohr, Steinbrink, Martin & Vasic, 2010). Deficits have been found in aspects of executive functioning including inhibition and sequencing. However, there is some inconsistency in the aspects of executive functioning in which a deficit may occur. For example Brosnan et al., (2002) found that dyslexic adults exhibited deficits in inhibition and sequencing, while dyslexic children only exhibited an inhibition deficit. Reiter, Tucha and Lange, (2005) found a mild inhibition deficit among dyslexic children when engaged in demanding tasks but not on simpler ones. Similarly Smith-Sparks, Fisk, Fawcett, & Nicolson, (2003) found significant differences in the performance of dyslexic adults and controls on a spatial memory updating task (the recall in serial order of the positions of the last four items in a sequence) as the task became harder. And, Helland & Asbjornsen (2000) identified deficits in dyslexic children in several aspects of executive functioning, including the ability to maintain focus on relevant stimuli, and to change focus. Thus, numerous studies have documented some impaired executive functions in dyslexic populations, and although no clear pattern has emerged across abilities, weakness in the ability to inhibit responses seems to be frequently observed among dyslexic children.

Implicit Learning Deficit: Theory and Evidence

Implicit learning refers to the ability to learn patterns or regularities without conscious attention or effort to learn. Implicit learning occurs unintentionally and unconsciously, and can also be described as passive learning. It is contrasted with explicit learning, which is an active process where individuals seek out information. Implicit learning is important in learning skills such as riding a bicycle, however, reading researchers argue that it should also be implicated in orthographic learning (e.g., Pacton, Fayol, & Perruchet, 2005). For example, even very young readers are sensitive to various regularities of their spelling system (such as the fact that English words can end in doubled consonants but can not begin with them) despite never having been taught this pattern explicitly (Cassar & Treiman, 1997). It has been argued that dyslexic individuals may have a deficit in this type of learning, because one of their hallmark difficulties is specifically in learning and applying accurate spelling knowledge. Although some researchers see implicit learning as a domain naturally suited to literacy learning, the tasks that have been traditionally used to assess this ability do not involve any learning of 'real' spelling patterns. One of the most commonly used tasks is called the *Serial Reaction Time* task in which participants need to detect certain visual items from serially-presented sequences of items. Unbeknownst to the participant, the stimuli occur either in a structured, predictable sequence, or, in a random sequence. If implicit learning occurs, the individual should perform more quickly on the patterned trials than on those that are randomised.

Summary of findings of Implicit Learning Deficit

There is a paucity of research in this area and the results to date have been inconsistent. A number of studies have found that dyslexics exhibited an implicit learning deficit (Menghini, Hagberg, Caltagirone, Petrosini, & Vicaria, 2006; Vicari et al., 2005 & Vicari, Marotta, Menghini, Molinari, & Petrosini, 2003). The deficit was found on both sequential and procedural learning tasks in dyslexic children and on sequential learning tasks in dyslexic adults (Menghini et al., 2006; Vicari et al., 2005 & Vicari, et al., 2003). However, other studies have found dyslexics not to be deficient in implicit learning. Kelly, Griffiths and Frith, (2002) found no implicit learning deficit in dyslexic university students on motoric and cognitive sequential tasks, and, Roodenrys and Dunn (2008) found dyslexic children to be unimpaired on implicit learning in a simple cued reaction time task.

Automatisation/Cerebellar deficit: Theory and Evidence

In a number of studies by Fawcett and Nicolson, dyslexic children were found to have problems 'across the board', on tasks including balance (Fawcett & Nicolson, 1992b; Nicolson & Fawcett, 1990), motor skill (Fawcett & Nicolson, 1995b), phonological skill (Fawcett & Nicolson, 1995a), and rapid processing (Fawcett & Nicolson, 1994). This pattern of difficulties was attributed to the *automatisation deficit hypothesis* (Nicolson & Fawcett, 1990),

which proposes that dyslexic children have problems in fluency for any skill that should become automatic with extensive practice. This hypothesis implicates the cerebellum as a brain structure that underlies failures in automatisation.

Much of the recent research on automaticity has concentrated on balance problems in dyslexia. A meta-analysis of balance deficits in 17 papers (Rochelle and Talcott, 2006) identified effect sizes of between 0.44-0.78 in the studies analysed, providing moderate support for this deficit. However, the authors found substantial variability across the studies and concluded that the association of poor balance with dyslexia was moderated by the presence of other difficulties and by levels of IQ; in other words, "deficits of balance may indicate increased risk of developmental disorder, but are unlikely to be uniquely associated with dyslexia." (pp. 1159). Several researchers have argued that balance problems may relate more particularly to attention deficit disorder (ADHD), which is sometimes comorbid with dyslexia (Wimmer, Mayringer, and Raberger, 1999; Rochelle, Witton, & Talcott, 2009). From a more applied perspective, Berninger and her colleagues (2008) have noted the impact of lack of automaticity in writing and spelling on response to intervention in dyslexic children, although they link these difficulties to weaknesses in executive functions.

Problems in motor skill and automatisation may be associated with dysfunction in the cerebellum. Fawcett and colleagues proposed that a cerebellar deficit could explain the range of problems suffered by children with dyslexia, and tested this idea looking first at behaviour and then at the brain. Nicolson, Fawcett and Dean (1995) reported that dyslexic children showed a pattern of poor performance on time estimation, a task that Ivry and Keele (1989) found only in cerebellar patients. Children with dyslexia also showed a range of classic cerebellar signs (Fawcett and Nicolson, 1999; Fawcett, Nicolson and Dean, 1996) with problems in muscle tone and balance in 80-90% of the children tested. Nicolson, Fawcett and Dean (2001) also found that dyslexics require longer to acquire even the most basic motor skills, such as pressing buttons, and that they may also have abnormalities in fundamental learning processes such as classical conditioning, habituation, response 'tuning' and error elimination in eye blink conditioning study (Nicolson et al., 2001; Coffin, Baroody, Schneider, & O'Neill 2005). However, there is controversy about the extent to which the above difficulties are specific to dyslexia; they may better be explained by the common overlap with DCD and ADHD (see Chapter V).

Three recent reviews best summarize the state of the art in this research area. Stoodley and Schamaman (2009) showed that the cerebellum was involved in motor , somatosensory , language , verbal working memory , spatial , executive function and emotional processing. In her evaluation of this area of research, Bishop (2002) proposed methodological improvements for advancing research, in particular in the neuroimaging studies of cerebellar deficits in dyslexia. These improvements include (1) assessing more clearly whether the dyslexic participants show signs of poor automatisation in reading (i.e. are slow readers), (2) testing for signs of concomitant language impairments, (3) testing for behavioural signs of poor motor function, as a proxy for cerebellar dysfunction, (4) investigating whether the participant has a family history of dyslexia, and where possible (5) testing for impairments of magnocellular functioning (see below), as these have been proposed to be clearly associated with cerebellar dysfunction.

A recent review, Stoodley and Stein (2009) has concluded that, although "it is likely that the cerebellum is part of the disturbed neural circuitry that is impaired in developmental dyslexia" (pp. 1), there is considerable inconsistency in the research findings and many studies find no evidence of general impairments in automaticity, or of cerebellar impairments; these authors conclude that "it remains unlikely that cerebellar dysfunction is the main cause of dyslexia" (pp. 1). In sum, as in many areas of research into dyslexia, the cerebellar impairments hypothesis awaits further investigation and refinement. At present, the evidence suggests that some people with dyslexia have impaired cerebellar functioning, however the causal connection between these two disorders remains unclear.

Sensory Magnocellular Deficits

Another area of research has focused on dyslexic children's difficulties in processing information coming in via the senses (sensory information); that is, information coming from both the ears (auditory) and the eyes (visual). This type of processing is controlled by the large cells in the magnocellular pathways, which go to a part of the brain

known as the thalamus. Differences have been found in the dyslexic brain anatomy in both visual and auditory magnocellular pathways (Galaburda, Menard and Rosen, 1994; Livingstone, Rosen, Drislane & Galaburda, 1991).

Auditory perceptual deficits

According to this theory (Tallal, 1980), the *phonological deficit* is the consequence of a more basic deficit in the auditory processing stream. Proponents of this theory claimed that, like language disordered children, those with dyslexia take longer to process sounds which change rapidly (Tallal, Miller, & Fitch, 1993). This is tested with the Auditory Repetition Task (ART) in which high and low tones, or the sounds *ba* and *da* are presented (which only differ from each other in the first few milliseconds), and the listener has to reproduce the order in which the sounds occurred. Children with dyslexia and with SLI were unable to tell the difference between the sounds if they were presented in quick succession, and this difficulty was associated with poor phonological awareness. This potentially important theory attracted a number of attempts at replication, and as a consequence the auditory deficit is now better understood. It is now clear that the ART deficit is found in some children with language impairments, of whom some may also have reading difficulties. For example, the carefully designed study of Heath, Hogben, and Clark (1999) revealed that dyslexic children who had no concomitant oral language problems were as good as typical readers on the ART task; in contrast, 55% of the children with oral language difficulties and dyslexia experienced significant difficulties on the ART while the remaining 45% (with less severe language impairments) were comparable to typically developing children. Moreover, ART performance and phonological skills were weakly associated. Thus, auditory processing deficits are found among some children with dyslexia who also have language impairment; but, importantly, this difficulty seems not to be a direct cause of their literacy difficulties.

Visual processing deficit

A problem in the processing of low-level visual information in people with dyslexia was first identified by Lovegrove (1993; Lovegrove, Martin and Slaghuis, 1986), who found that if a flickering pattern was shown to dyslexic children (think of the lines on a television screen), they needed a more defined flicker before they were aware of it. Along similar lines, Talcott et al. (1998) showed that dyslexic children needed more information to detect a pattern of stimuli moving together, like clouds, against a randomly moving background (a task known as *coherent motion sensitivity*).

However, more recent research in this area has failed to find a magnocellular deficit among dyslexics. For example, in a study with children, Hulslander et al. (2004) found no difference between good and poor readers (including some with dyslexia) on a measure of motion coherence sensitivity (cf., Talcott et al., 2000). Moreover, reading ability and motion sensitivity thresholds did not correlate when IQ was taken into account; however, the two groups differed significantly on phonological awareness. Using a different measure of magnocellular function (detecting a low-spatial frequency flickering stimulus), Williams, Stuart, Castles and McAnally (2003) found no differences between groups of dyslexic and control children. And, in a recent large-scale study with adults, Heath, Bishop, Hogben and Roach (2006) found that two common measures of magnocellular processing (coherent motion and flicker sensitivity) correlated poorly with each other, raising the possibility that they do not reliably tap magnocellular function – or that they are not functionally related to each other. In addition, these authors found a small subgroup of dyslexic adults to perform less well than a control group on the two visual tasks, however, neither of these tasks correlated with reading ability. A similar finding was observed by Ramus et al. (2003), and by Judge et al. (2006). Thus, yet again, it seems that sensory deficits in vision and audition may occur in some individuals with dyslexia, however their connection to dyslexic literacy difficulties is tenuous, and probably not causal. Despite the inconsistencies in the research findings, this continues to be an active area of research (e.g., Laycock & Crewther 2008; Poldrack et al., 2001), which promises to advance our understanding of perceptual deficits of vision and hearing, if not necessarily in dyslexia.

Visual Attention Deficit

In contrast with visual perception processes, visual attention (not to be confused with Attention Deficit Hyperactivity Disorder) refers to how attention is distributed when focusing on particular stimuli (Valdois, Bosse, & Tainturier, 2004). However, visual attention does not refer to a unitary construct. For example, tasks to assess visual attention include measures of the ability to direct and focus attention, to detect visual objects in a scene,

and tasks include tests of visual capacity (analogous to verbal memory span) which provide an estimate of the total amount of information that can be obtained from a brief visual display (Valdois et al. 2004).

Summary of research findings on visual attention deficit

A hypothesis that has been gaining momentum in recent years suggests that dyslexia is also associated with visual attention deficits. Evidence has been presented suggesting that visual attention plays a role in reading (e.g. Bosse & Valdois, 2009; Shaywitz & Shaywitz, 2008). Moreover, Valdois et al. (2004; also Bosse et al., 2007) have argued that, among children with dyslexia, visual attention skills make a contribution to reading independently of phonological skills, and that the visual attention problems may be viewed as a second 'core deficit' in dyslexia (second to the phonological deficit). Accordingly, Valdois et al. (2003) identified dissociations with some dyslexics performing well on phonological tasks but poorly on measures of visual attention, whereas others showed the opposite pattern. In other studies, individuals with dyslexia have been reported to have deficits on visual search tasks (e.g., Buchholz & McKone, 2004; Iles, Walsh & Richardson, 2000; Roach & Hogben, 2004; Vidyasagar & Pammer, 1999), on the attentional blink task (Buchholz & Davies, 2007; Hari, Valta & Uutela, 1999), and on covert spatial orienting tasks (e.g., Buchholz & Davies, 2005; Facoetti, Paganoni, Turatto, Marzola, & Mascetti, 2000; Facoetti, Turatto, Lorusso, & Mascetti, 2001; Facoetti et al., 2006).

As with research into the sensory deficits, however, the findings on visual attention deficits in dyslexia have been mixed. While a number of studies provided evidence of a deficit in some aspect of visual attention in *some* dyslexic individuals, including children and adults (Bosse et al., 2007 ; Buchholz & Davies 2005; Heiervang & Hugdahl 2003 & Roach & Hogben, 2007), others did not find such deficits (Judge, Caravolas, & Knox, 2007). Hawelka and colleagues have reported evidence from a simple serial order task (Hawelka, Huber, & Wimmer, 2006; Hawelka & Wimmer, 2005) that differences between dyslexics and controls appear to be obtained only when responses require verbal processes (such as verbally rehearsing the order of the objects), suggesting that it is the linguistic elements of the task that may underlie dyslexics' observed difficulties on visual attention tasks (see also Hawelka & Wimmer, 2008; Pitchford, Ledgeway, & Masterson, 2009). Although it seems likely that visual attention plays a role in reading skill, the specific aspects of attention that might be impaired and cause reading difficulties has yet to be determined.

While such conflicting reports may be frustrating for practitioners and policy makers, they are in fact a sign of a healthy state of affairs in dyslexia research. As Hogben and colleagues (e.g., Badcock, Hogben and Fletcher, 2008; Roach & Hogben, 2008) have clearly illustrated in several recent studies, methodological differences between studies in the way various phenomena are being tested, the selection and assessment of dyslexic participants, and differences in statistical approaches can lead to very different findings and conclusions.

Summary

- All the theories account for at least some of the observed symptoms of dyslexia at least in some dyslexic individuals; differences associated with these deficits are sometimes observable in brain scans.
- The phonological deficit explains many of the difficulties which children show linking sounds with symbols in reading and spelling. It is accepted by most to represent the core deficit in dyslexia.
- The RAN or double deficit suggests that there is a naming speed problem in addition to, or as an aspect of the phonological deficit, with problems most severe for those with both deficits.
- The verbal short-term memory deficit is a very common marker of dyslexic difficulties, and is considered to represent an aspect of phonological processing.
- The sensory deficits research suggests that for some individuals, basic perceptual-level visual as well as auditory problems are associated with dyslexic difficulties, although they may not be a direct cause of dyslexia.
- The cerebellar deficit could explain difficulties in the development of motor skills, that require precise timing and co-ordination of different muscle groups, such as handwriting, but seems to relate more to co-existing developmental disorders, such as ADHD.
- The central executive functioning system could be a site of common cognitive deficit in dyslexia and ADHD, which may explain the high degree of overlap between the two disorders.

Across theoretical perspectives presented above, it remains to be clarified (i) what are the underlying causes of some of the manifest difficulties, (ii) which difficulties are coincidental to the core dyslexic difficulties, and (iii) which difficulties are the consequences of the deficits that also cause poor literacy development.

III.ii Biological Bases of Dyslexia

There is now clear evidence that dyslexia is heritable (Byrne et al., 2009; DeFries, Vogler, & LaBuda, 1986). Population genetic studies of family risk reveal that 40% of boys and 18% of girls with a dyslexic parent are also dyslexic (Pennington & Smith, 1988), and large-scale twin studies reveal that approximately 50% of the differences in reading ability between dyslexic and nondyslexic readers are attributable to genetic differences (DeFries, Fulker, & LaBuda, 1987; Wagner, 2005). Studies in molecular genetics have produced evidence that corroborates the heritability findings. These studies seek to identify the specific locations on genes that are implicated in dyslexia. Three gene loci were initially identified linked to dyslexia in family studies: chromosomes 6, 15, and 2, but more recent research reveals that the risk of inheriting dyslexia will depend upon complex sets of genes that have interactive effects (e.g., Cope et al., 2005; Gayan et al., 1999; Grigorenko, 2001). This is not surprising in view of the complexity of reading ability in itself. A recent study, in which the whole genome was scanned, further identified other possible loci on chromosomes 3, 13, 18, 21, and X (Fisher et al., 2001). In her meta-analysis of the studies of key dyslexia genes, Grigorenko (2005) concluded that further research is likely to reveal many more loci of risk of dyslexia, and a picture will emerge that is still more complex than is currently evident. The most up-to-date references are provided in national and institutional websites such as OMIM (http://www.ncbi.nlm.nih.gov/entrez/dispomim or http://www.ensembl.org. For reviews of the area see Ramus, 2006, Fisher, 2006; Pennington, 2009).

It is important to bear in mind, as more genes associated with dyslexia are identified, that genes do not 'explain' the disorder, and that abnormalities in these loci do not inevitably imply reading problems. It is very important to remember that the brain develops from a complex and unpredictable interaction between the genes, the environment, and concurrent brain development. One theory (Plomin & Kovas, 2005) predicts that there are many 'generalist genes' which can have multiple effects on the brain as it develops, and these may account for the overlap or comorbidity between learning disabilities. One of the challenges for dyslexia research is to identify how a child's early environment may be adapted to provide the best conditions for brain and cognitive development, so as to minimize the weaknesses and maximize the strengths of each child. Recent longitudinal studies (Lyytinen et al., 2005; Snowling, Gallagher, & Frith, 2003; Molfese, 2000) have begun to look at these issues. An ongoing longitudinal study of 615 twin pairs in early childhood (Byrne et al., 2009) has shown that most aspects of reading are strongly influenced by genes, and less by environment. This study again highlights the impact of risk factors, and establishes that *vocabulary learning* and *print knowledge* are some of the most important factors determining success, with attention and processing speed playing an important role as children develop their skills.

Summary

There is considerable potential in genetic research, as new screening techniques make this more easily accessible. However presence of a gene does not necessarily determine outcome. It is important not to assume that 'genetic' risk means the child is destined to fail, indeed early intervention studies with 'at risk' groups show a number of protective factors which can help children keep pace with their peers. The challenge now is to 'join up' the genetic research with the theoretical research at the brain and cognitive levels, with applied research using information from a range of different studies in a technique called 'converging operations' to identify the underlying causes and best practice for support of children with dyslexia. However the impact of gene research on educational intervention and outcomes is still a long way away.

IV. CROSS-LINGUISTIC FACTORS IN THE EXPRESSION OF DYSLEXIA

IV.i Summary of Research on Cross-linguistic factors and Multilanguage Factors in Dyslexia/Learning Disorders

Although the existence of dyslexia among individuals of many different language backgrounds is well established, a widely held popular misconception persists nevertheless, that dyslexia is a condition found only in the English language, and this is due to its comparatively "confusing" spelling system. In fact, dyslexia has been identified not only in English and other European languages but also in languages with other alphabetic scripts, like Arabic and Hebrew, and in non-alphabetic scripts, such as Chinese, Japanese, and Kannada (See Caravolas, 2005 for review; also Abu-Rabia, Share & Mansour, 2003; Seki, Kassai, Uchiyama, & Koeda, 2008).

However, the manifestations of the disorder may differ somewhat depending on the language spoken, and especially on the extent to which the language has an orthography that links spoken and written language in a transparent and consistent way. For example, unlike English, languages such as Welsh, Czech and German have fairly predictable and transparent mappings between letters and speech sounds, and this makes them easier to read and spell than English (e.g., Caravolas & Bruck, 1993; Ellis & Hooper, 2001; Landerl, Wimmer & Frith, 1997). Studies in which dyslexic children learning such transparent orthographies have been compared to English-speaking dyslexics, typically report that dyslexics exhibit greater impairments in English than in other languages not only in reading and spelling, but also in related skills such as phoneme awareness, and orthographic awareness (Caravolas, Bruck, & Genesee, 2001; Caravolas, Volín, & Hulme, 2005; Katzir, Shaul, Breznitz & Wolf, 2004; Landerl, Wimmer, & Frith, 1997; Ziegler, Perry, Ma-Wyatt, Ladner, & Schulte-Körne, 2003; Ziegler & Goswami, 2005). In reading, it is typically found that dyslexic readers of transparent orthographies read relatively accurately, but very disfluently, while English dyslexics tend to be both inaccurate and dysfluent.

Despite these differences in levels of performance, however, there is increasing evidence of similarities in the types of impairments experienced by dyslexic individuals, especially across languages with alphabetic orthographies. Ziegler et al. (2003) found that German and English dyslexics exhibited similar deficits in speed, phonological decoding and non-word reading deficits when compared to age matched and reading level controls. Ramaa, Miles and Lalithamma (1993) found that the pattern of dyslexia among children from South India who speak the Kannada language was similar to that of the English language, with the dyslexics exhibiting phonological processing deficits in both languages. Finally, Caravolas et al. (2005) found that, although English dyslexic children experienced a greater degree of difficulty on literacy and phonological tasks than Czech children, both groups of dyslexics exhibited a comparable degree of deficits relative to their typical reader controls. Importantly, there is accruing evidence that most dyslexic readers of alphabetic orthographies have impairments in phonological processing skills – be they at the level of accuracy or speed, reading fluency, and/or spelling (Caravolas, 2005).

A slightly different picture emerges for dyslexics learning to read and spell the *non-alphabetic* orthography of Chinese in which the visually complex orthographic characters relate information about meaning and only partially about sound. Research on this topic shows that, although the *same basic component skills* are involved in reading a script like Chinese as in other languages, they are weighted differently, such that visual processes play a larger role than phonological processes in both typical and atypical reading processes (e.g., Ho, Chen, Tsang, & Lee, 2002; Siok, Niu, Jin, Perfetti, & Tan, 2008), and moreover, awareness of morphology (i.e., the meaningful components of words) plays a key role in learning to read (McBride-Chang et al., 2003; Shu, McBride-Chang, Wu, & Liu, 2006).

IV.ii Dyslexia in Bilingual Populations

Information regarding dyslexics, who are also bilingual, is limited as research on this population is sparse and has focused mainly on screening and assessment (Everatt, Smythe, Adams, & Ocampo, 2000; Frederickson & Frith, 1998; Guron & Lunberg, 2003). In general the research findings indicate that screening/assessment measures used for identifying monolingual dyslexics are equally effective for identifying bilingual dyslexics (Everatt, Smythe, Adams, & Ocampo, 2000; Frederickson & Frith, 1998 & Guron & Lunberg, 2003). Everatt, Smythe, Adams and

Ocampo, (2000) found that screening measures used for assessing SpLD were effective for identifying English monolingual children with learning disabilities as well as English/Sylheti bilingual children. In particular, the assessment of phonological skills appears to be equally effective in identifying monolingual and bilingual dyslexics (Frederickson & Frith, 1998; Guron & Lunberg, 2003). In a Swedish study, Guron and Lunberg, (2003) found that the same battery of tasks were effective in assessing the phonological skills of monolingual Swedish speakers and multilingual speakers for whom Swedish is an additional language. Similarly, Frederickson and Frith (1998) found that phonological processing tests were effective in identifying dyslexia among bilingual Sylheti/English speakers in England.

However there is some concern about the use of the IQ discrepancy approach, which has been popular until recent times, to assess bilinguals for dyslexia and other learning difficulties (Frederickson & Frith, 1998; Cline, 2000). It is thought that this approach may result in fewer bilingual children being assessed as dyslexic because English IQ tests tend to underestimate the cognitive skills of children for whom English is an additional language (Cummins, 1984 as cited in Frederickson & Frith, 1998). Additionally, IQ tests administered in English may not be valid and reliable ways of assessing bilingual children who are still developing proficiency in English (Cline, 2000). In fact a Scottish study which investigated the processes involved in identifying and assessing bilinguals suspected of being dyslexic, suggests that there is an underrepresentation of bilingual dyslexics relative to monolingual dyslexics (Deponio, Landon, Mullin, & Reid, 2000).

In terms of the manifest difficulties among bilingual dyslexic individuals, there is some evidence that they are largely similar to those exhibited by monolingual dyslexics (Oren & Brenznitz, 2005). In a study examining the differences between dyslexic and non dyslexic Hebrew/English bilinguals Oren and Brenznitz (2005), found that the dyslexics were significantly slower and less accurate when processing information in both languages. Additionally, the performance of the dyslexics was also affected by the orthography with greater impairments (slower and less accurate) in English.

To summarise, dyslexia exists across different languages. There are a number of similarities as well as subtle differences in the manifestations of the disorder across languages, which have been mainly (but not exclusively) accounted for by the orthography of the language. The main differences are observed in the degree of the severity of the impairments exhibited in reading accuracy and phonological awareness accuracy, with English speakers showing more serious impairments. Similarities include deficits in phonological fluency, including rapid naming (RAN). These differences and similarities should be considered in the assessment, intervention and support of dyslexics.

IV.iii Dyslexia and SPLD in Welsh

Due to the limited number of studies on Welsh and in particular on dyslexia among Welsh speakers, all available studies investigating reading with Welsh speakers were included in this review. Consistent with other cross-linguistic findings, research to date indicates that reading acquisition may be easier and quicker in Welsh than in English (Ellis & Hooper, 2001; Spencer & Hanley, 2003, 2004). Ellis & Hooper (2001) investigated the rate of reading development in samples of typical Welsh and English 6 to 7-year-olds. They found that the Welsh speaking children read more accurately (but not more quickly) than their English speaking peers. The Welsh children also used a more sequential (synthetic) reading strategy than the English children, who often guessed at words they could not read easily. The researchers concluded that this was due to the orthographic transparency of the Welsh language.

Similar findings were also obtained in a study by Spencer and Hanley (2003) who investigated the relationship between the development of reading skills and the consistency of the orthography, by examining reading acquisition in Welsh speaking and English speaking children 5-6 years old. These researchers found that Welsh-speaking children were better at reading real words and nonwords, and at phoneme awareness than their English-speaking counterparts. Additionally an analysis of the reading performance of the lowest quartile of children (potentially having dyslexia) revealed that the English-speaking children showed a relatively greater lag

than their Welsh counterparts; the authors suggested that the Welsh poor readers were to some degree, but by no means completely, protected by their transparent orthography as compared with the English poor readers. In a follow up study Hanley, et al. (2004) sought to establish how long the advantage of learning to read a transparent orthography lasted by re-examining the same children at age 10. The results indicated that the reading skills of the English speaking children were now equivalent to those of the Welsh speaking children for regular words and only slightly weaker for irregular words. However the decoding skills of the lowest performing 25% of the English speaking children were still significantly lower than the lowest performing 25% of the Welsh speaking children. These findings are consistent with those observed in other languages with transparent orthographies, and they confirm that the manifestation of specific reading impairments may differ in severity depending on the language in which reading is acquired. One interesting and unexpected finding of this study was that despite being more accurate readers, the Welsh children scored less well in reading comprehension than their English peers. Thus, accurate and fluent reading does not necessarily guarantee good reading comprehension, and conversely, it would seem that error-prone reading does not necessarily imply poor reading comprehension. The relationship between the development of reading accuracy and reading comprehension across different orthographies and languages needs to be investigated further.

Another study by Mayer, Crowley & Kaminska (2007) extended the finding of better performance of Welsh speakers to other areas of literacy. They investigated the effect of orthographic depth on phonological recoding (the translation between written letters and corresponding sounds) in the reading and spelling of Welsh-English bilinguals. They found that Welsh speakers performed better than English speakers in spelling as well as reading. Finally, Thomas and Lloyd, (2008) found that Welsh-speaking dyslexic children performed worse than their peers on reading, spelling and text copying tasks.

It is difficult to draw very strong conclusions about the developmental profiles of the Welsh dyslexic children from the above studies because they were not specifically designed to assess children with dyslexia (with the exception of the Thomas and Lloyd study, which however included a small sample covering a wide age range), and thus they included only very small numbers of children at the tail end of the 'normal' distribution. As such they may have included children with other disorders or difficulties.

A very relevant issue for the Welsh context is to understand the impact of bilingualism on the manifestations of dyslexia, and on the methods of best practice for supporting dyslexic children in school. Despite the prevalence of bilingualism and multilingualism in the world's school-aged populations, very little research has been carried out to address this issue specifically (see section IV.ii above). Although it seems that bilingualism has long-term benefits on cognitive development in typically developing populations (Bialystok, 2007), and may even confer some protective advantages against cognitive decline in later years (Bialystok, Craik, & Freedman, 2007; Bialystok, Craik, Klein, & Viswanathan, 2004), it is not certain that bilingualism helps the dyslexic child to deal with his/her literacy and associated difficulties.

To summarise, these studies indicate that reading acquisition in Welsh appears to be easier than in English, mainly due to the greater orthographic transparency of the Welsh language. However, any advantage gained by learning to read in Welsh (relative to English) is limited and seems to wane by age 10. Additionally like their English speaking peers Welsh speaking dyslexics perform less well than non-dyslexics on reading speed, spelling, and phonological awareness. It is likely that the deficits in terms of speed of reading and phonological processing are more similar across the language groups than are accuracy deficits.

V. DYSLEXIA AND OVERLAPPING DISORDERS

By definition, individuals with dyslexia show deficits in reading, however these individuals often have difficulties in other areas, such as concentration, motor abilities and mathematics. Researchers have investigated the prevalence of other developmental disorders in the presence of Dyslexia, such as Attention Deficit Hyperactivity Disorder (ADHD), Developmental Coordination Disorder (DCD) Specific Language Impairment (SLI) and Speech Sound Disorder (SSD). Links have also been made between Dyslexia and Pragmatic Language Impairment (PLI), Autism Spectrum Disorders (ASD), arithmetic deficits (Dyscalculia) and emotional and behavioural difficulties.

Investigations conducted with individuals with dyslexia selected from both specialist clinics and from population samples have repeatedly found that the occurrence of additional developmental disorders in these children and adolescents is significantly higher than that found in individuals without reading deficits. This suggests that an individual is likely to have another developmental disorder as well as dyslexia than to have dyslexia only.

This overlap of conditions, often referred to as co-occurrence or comorbidity, has significant implications for education in terms of diagnosis, prognosis and educational intervention, and highlights the need to consider the child as a whole. If the presence of dyslexia is observed in an individual, it is important to consider the potential and likely presence of other developmental disorders. This is important in terms of considering the approach to support the individual and also the outcome from intervention. For example if a child has dyslexia and ADHD, then the child may be inattentive when undertaking a reading scheme with a learning support assistant. Such a child would benefit from a quiet working environment and from learning sessions that were broken into small chunks to maximise effectiveness. In the case of a child with dyslexia and dyspraxia, writing difficulties due to poor co-ordination, which impact on both spelling and writing could have implications for exam provision for the young person. A child with a speech and language difficulty may require information to be written down or spoken, with visual cues to ensure understanding as decoding the information only from written or spoken word may not be enough. A child with an autism spectrum disorder (ASD) such as Asperger's Syndrome and dyslexia may take tasks very literally and only be interested in a narrow range of information, so reading schemes may need to be directed towards their interests to be engaging for that individual. A young person with emotional and behavioural difficulties may have received behavioural interventions, however if his/her level of literacy is not assessed, possible underlying reading difficulties may not be recognised and addressed. These difficulties may have a continued impact on self esteem and behaviour, and the effectiveness of behavioural intervention may be minimal.

Definitions of the learning difficulties found to overlap with dyslexia, and an overview of some of the research regarding the existence and rate of co-occurrence of dyslexia with these developmental disorders is presented below.

Specific Learning Difficulties (SpLD): Definitions

ADHD	*Attention Deficit Hyperactivity Disorder* A term used to describe children who exhibit inattentive and/or hyperactive and impulsive behaviour more frequently and to a greater degree of severity than their peers.
DCD	*Developmental Coordination Disorder* A disorder characterised by movement difficulties that are out of line with age and developmental stage, that are not explained by neurological deficits, and significantly interfere with a child's academic achievement or activities of daily living. (In the UK this is often also referred to as Dyspraxia)
SLI	*Specific Language Impairment* A disorder in which oral language skills are impaired, but non-verbal ability is within the normal range.
SSD	*Speech Sound Disorder* A disorder characterised by the substitution or omission of sounds from words, with

	speech production errors hindering the intelligibility of speech; other language abilities are not affected.
ASD	*Autism Spectrum Disorder* A disorder characterised by impaired communication and social interaction and restricted and repetitive behaviour.
PLI	*Pragmatic Language Impairment* Describes individuals that have difficulty extracting the underlying meaning from language, for example comprehending inferences, understanding jokes and realising the intended, rather than the literal meaning of language. Often associated with Autism Spectrum Disorders.
Dysgraphia	A term used to describe writing skills that are substantially below those expected given a person's age, intelligence, and education. This is a subset of difficulties typically assumed to be a component of dyslexia.
Dyscalculia	Difficulty which affects the ability to acquire arithmetical skills, despite sufficient intellectual ability and motivation.

ADHD

ADHD is divided into three subtypes; predominantly inattentive, predominantly hyperactive/impulsive and combined type. In the classroom, a hyperactive child may often fidget, talk excessively, interrupt others, move around at inappropriate times, and appear to be constantly on the go. This ADHD subtype is more often seen in boys. The inattentive-type ADHD, more common in females, is characterised by frequent daydreaming, difficulty listening and following directions and a tendency to be easily distracted by external and internal stimuli. These children are less likely to be disruptive, are more likely to display internalising symptoms such as anxiety and depression. For a diagnosis of ADHD, difficulties must have been present from an early age, and be shown across different settings (e.g. at home and school).

It is not uncommon for parents and teachers to report a lack of concentration and attention in children with dyslexia (Snowling, 2000), and investigations into the co-occurrence of dyslexia and ADHD have found that overlap of these two disorders is frequent, both in clinical and community samples.

Dyslexia and ADHD

Research

- In a clinical sample of males with ADHD, August and Garfinkel (1990) reported that 39% of the group had reading and/or spelling scores below that predicted by age and IQ.
- Kadesjo and Gillberg (2001), in a Swedish study, screened over 400 schoolchildren for ADHD symptoms. Within a group of children meeting an ADHD diagnosis and a group with milder ADHD deficits, the percentage of the groups with reading/ writing problems (40% and 29%, respectively) was higher than that seen in a group of children without ADHD symptoms (7%).
- Stevenson et al., (2005) recruited children with ADHD from clinics, and found that 54% of this sample also had a reading disability.
- Willcutt, Pennington, Olson, & DeFries (2007) investigated a population sample of twins, with at least one twin member with reading disability (RD) or ADHD (known as a proband twin). Forty percent of the proband twins met criteria for the other disorder. The patterns of comorbidity in the twin pairs suggested that the co-occurrence of these two disorders is largely attributable to genetic influences.
- Bental and Tirosh (2007), in a study in Hebrew, found that a group with both ADHD+RD showed unique deficits in rapid naming, and more severe difficulties with verbal working memory than 'pure' ADHD or RD groups, suggesting that these areas may be important in explaining comorbidity.

Dyslexia and ADHD: Summary

A number of studies have looked at the overlap between reading and inattention/ ADHD, and estimates of the co-occurrence of these problems range from 25-50%, and far exceed the overlap that would be expected by chance.

The reason for this is unclear; shared genetic causal factors may explain some of the overlap, some areas of cognition have been implicated such as deficits in rapid naming, or symptoms of inattention may be secondary to a primary reading deficit.

DCD

DCD, also known as dyspraxia, is characterised by motor difficulties that have a significant effect on activities of daily living and education. Children with DCD may have difficulties at school with writing, drawing, sports and games and at home with self-care tasks such as dressing, eating and drinking. Difficulties with organisation and planning may also be apparent.

Dyslexia and DCD

Research

- O'Hare and Khalid (2002) reported that 70% of a group of children with a DCD diagnosis had parent-reported reading difficulties, in comparison to 14% of a group of children without DCD.
- Iversen, Berg, Ellertsen & Tonnessen (2005), identified two groups of poor readers, one group of children with a dyslexia diagnosis and another group of teacher-identified poor readers, and compared these to a group of good readers on performance on a standardised assessment of movement (Movement Assessment Battery for Children; M-ABC). The poor readers had significantly poorer movement scores than the good readers, with 60% of the clinical group and 53% of the teacher-identified poor reader group showing severe difficulties warranting a possible DCD diagnosis.
- Rochelle and Talcott (2006) report results from a meta analysis of studies looking at balance and dyslexia, and postulate that balance deficits are more strongly related to third variables, such as co-occurring ADHD and IQ, than reading ability.
- Cruddace and Riddell (2006) screened a non-clinical sample of schoolchildren, and found reading difficulties (RD) co-occurred with movement difficulties (MD) more often than expected if the two sets of deficits were independent. Children with MD with or without RD showed deficits on measures of attention, however children with RD only were comparable to a control group on these measures.
- Haslum and Miles (2007) looked at motor, reading and spelling test results from a national cohort of 10 year old children and found increased motor difficulties based on five tests of motor performance in those children categorised as most likely to have Dyslexia.
- Berninger, Nielsen, Abbott, Wijsman, & Raskind (2008) notes that writing problems in developmental Dyslexia are under-recognized and under-treated. This study investigated 122 children with Dyslexia, and found impairments in handwriting, spelling and written composition in this group.

Dyslexia and DCD: Summary

Poor motor skills are often noted in children with Dyslexia and research shows that DCD and reading difficulties do co-occur. O'Hare and Khalid (2002) argue that children diagnosed with DCD may benefit from additional phonological awareness screening. If a deficit is found in this area, early interventions can be put in place, which may subsequently result in an improved reading prognosis. Handwriting is an area of difficulty associated with DCD, and handwriting problems have been reported in cases of Dyslexia (Cooke; 2002, Snowling, 2000) therefore this is also an area that children with Dyslexia may need help with.

It has been suggested that children with Dyslexia should be screened for writing difficulties, and if at risk, they should receive intervention and monitoring. If children respond to intervention to tackle reading problems, ongoing, explicit writing instruction also needs to be considered (Berninger et al., 2008).

SLI and SSD

SLI is characterised by delays in language development. Children with SLI may have difficulties with grammar, syntax and the semantic aspect of language. For example, a child with SLI may pronounce single words correctly, but may link words incorrectly when forming sentences, or miss words out. SSD involves impairments in speech-

sound production, and may involve the omission or the incorrect use of certain sounds, or phonemes (for example, pronouncing 'do' instead of 'dog', or 'ti' instead of 'be').

These language and speech impairments are traditionally diagnosed in the preschool years, and may be less apparent by the time the child starts to learn to read, instead the child may show difficulties associated with dyslexia. The link between early speech and language impairment and the increased risk of dyslexia may be missed because of this. Research has investigated these disorders, and their association with later reading difficulties.

Dyslexia, SLI and SSD
Research • Snowling, Bishop and Stothard (2000) investigated if language impairment in preschool is a risk factor for dyslexia in adolescence, reporting that children with SLI in the preschool years did less well on tests of reading, spelling and reading comprehension when followed up at 15 years old in comparison to a group of children that had not demonstrated language impairments at an early age. • Sices (2007) investigated the pre-academic reading and writing readiness of children of preschool children with SSD, with and without the presence of SLI. This study found a negative association with language impairment and readiness to read and write. However, SSD disorder did not have an effect on these test scores once language impairment had been taken into account in this instance. • Pennington and Bishop (2009) reviewed the relationship between speech, language and reading disorders, stating that there is evidence that SSD and SLI co-occur, and that SLI and later reading difficulties are comorbid. There is less data published regarding the relationship between SSD and later reading difficulties, however while SSD does not seem to cause reading problems on its own, in combination with SLI it appears to carry the most risk for dyslexia in later life.
Dyslexia, SLI and SSD: Summary Initial investigations considered dyslexia and speech and language disorders as distinct; however more recent research has investigated the occurrence of SLI and/or SSD and the development of later dyslexia. There is evidence that difficulties and delays in language development are more common in children with dyslexia in comparison to controls. Reports of the prevalence of dyslexia in cases of early language impairment range from 25-90% (Tomblin, Zhang, Buckwalter, et al., 2000). A 'severity hypothesis' has been put forward, suggesting that Dyslexia and SLI are different representations of the same underlying disorder, however the findings of Snowling et al. (2000) oppose this theory, and suggest that the developmental course for these two disorders is different. Specifically, while dyslexia is a language disorder that is underpinned by a deficit in phonological processing, SLI involves broader language impairments of semantics, grammar, and syntax. While the reading difficulties of dyslexics affect the domain of word decoding and recognition and spelling, in SLI they include reading comprehension, and in later development also dysfluent reading (Bishop & Snowling, 2004). Findings of a negative association between SLI and readiness to read and write highlight the potential value of integrating instruction in pre-literacy skills into intervention programs for preschool children with language impairments.

<u>ASD and PLI</u>

Autism Spectrum Disorders are characterised by impairments in communication and social interaction and a need for routine and repetitive behaviour. The term 'spectrum' is used as the characteristics of the condition can vary between individuals. At the severe end of the spectrum, an individual may show profound developmental delays, with little or no speech; at the other end, children with high-functioning autism or Asperger's syndrome may have an above average IQ, but have some difficulties with social communication, for example understanding language in the literal sense and misinterpreting social cues. PLI (Pragmatic Language Impairment) is a term used to describe difficulties in the understanding of how language is used in social contexts, and shares some of the characteristics of SLI (such as grammar and word finding difficulties) and can be associated with mild social difficulties similar to those seen in high-functioning autism/ Asperger's syndrome.

Dyslexia, ASD and PLI
Research • Nation, Clarke, Wright & Williams (2006) found normal levels of reading accuracy when looking at the average performance of a group of children with ASD. However, on closer inspection of individual cases there was a great deal of variability within the group, with many participants having difficulties when reading non-words relative to their word reading abilities, which may reflect a phonological deficit similar to that associated with dyslexia. • Griffiths (2007) found in an investigation of the pragmatic competence of dyslexic students, this group to be more impaired when deriving inferential information from a story and selecting the correct punch line for a joke in comparison to students without dyslexia. This may be the product of a reduced working memory capacity.
Dyslexia, ASD and PLI: Summary ASD is usually associated with relatively good word reading skills and impaired comprehension, however samples selected for research often favour the higher functioning end of the autistic spectrum so may result in an overestimation of levels of reading accuracy in autistic children. Rote memorisation or visual association strategies of word reading may be used in some cases, masking phonological difficulties. Recent research suggests that some autistic children may have reading difficulties similar to those associated with dyslexia and so may benefit from similar remediation. Difficulties with pragmatics of language are often associated with ASDs, however research highlights that some dyslexic children may also have difficulties in this area. This may mean some children with dyslexia are impaired socially and may have difficulty following instructions and keeping up with classroom interactions.

Dyscalculia

Specific difficulty in learning and understanding mathematics is known as Dyscalculia. Children may have difficulty with number concepts, number facts, and estimation. There is evidence for a relationship between reading and mathematics ability in typically developing children, and investigations into the occurrence and type of mathematics deficits in individuals with Dyslexia have been investigated.

Dyslexia and Dyscalculia
Research • Knopik, Alarcón and DeFries (1997), in a twin study, report evidence of shared genetic influences for maths and reading difficulties. • Dirks, Spyer, van Lieshout & de Sonneville (2008) assessed the prevalence of combined reading and arithmetic difficulties in 799 Dutch schoolchildren, and found that 7.6% of the group had both combined difficulties in reading and mathematics, a higher co-occurrence than that expected by chance. • Simmons and Singleton (2008) in a review of the literature on dyslexia and mathematical ability, argued that the majority of evidence points to a negative impact of phonological deficit on maths ability. Children have difficulties in those areas of maths that require phonological representations, such as recalling number facts, but may perform at average level in other areas. • Landerl, Fussenegger, Moll & Willburger (2009) discussed two possible accounts for co-occurring maths and reading difficulties; the common deficit account states that dyscalculia caused in some way by phonological-verbal deficits and the domain -cognitive deficit account assumes the two disorders have two separate cognitive profiles. The authors present evidence that there are different cognitive deficits in each disorder.
Dyslexia and dyscalculia: Summary Evidence from research suggests that Dyslexia is associated with difficulties with some aspects of maths. Individuals with Dyslexia may show different patterns of strengths and weaknesses in mathematics, for example some children may have difficulty recalling number facts, but no impairment with abstract mathematical reasoning. Some children may have a more profound difficulty with mathematics, and problems with the basic concept of numerosity. Therefore there is a need to use a range of mathematical tasks rather than a global score,

in order to screen and pin point underlying difficulties. It is important to recognise that problems with reading may spill over into maths. As the child moves up the school system the need to read and interpret mathematical problems with different instructions may increase and make the task hard, rather than the numbers alone.

Emotional and behavioural difficulties (EBD)

Links have also been made between reading ability and emotional and behavioural difficulties. Children with behavioural difficulties may present as avoiding reading, and may miss significant time in lessons. Children with dyslexia may have lowered self esteem and when being asked to read out aloud, or do tasks where their reading level is not sufficient to access materials, they may 'act out' their feelings. This may result in their behaviour being targeted for support.

Dyslexia and EBD

Research

- Maughan, Pickles, Hagell, Rutter & Yule (1996), in a longitudinal study of children with earlier reading difficulties reported an increased risk of behaviour problems in middle childhood, but not for antisocial behaviour in adulthood.
- Fergusson and Lynskey (1997) found an association between reading difficulties displayed at 8 years of age and later conduct problems, but found that this relationship was adequately explained by confounding factors, most notably early behaviour problems recorded at 6 years old.
- Tomblin, Zhang, Buckwalter & Catts (2000) reported an increased risk of behaviour disorder (BD) in reading disordered children.
- Place, Wilson, Martin & Hulsmeier (2000), in a study of pupils attending a primary school EBD provision, found that 75% had a reading age that was at least two years below their chronological age.
- Maughan, Rowe, Loeber & Stouthamer-Loeber (2003) reported evidence of an association between reading problems and depressed mood.
- Morgan, Farkas, Tufis & Sperling (2008), in a longitudinal study, found that children with reading problems in the first grade (Year 2) were significantly more likely to display poor task engagement, poor self-control, and externalising and internalising behaviour problems in third grade (Year 4).

Dyslexia and EBD: Summary

Children displaying emotional and behavioural difficulties may have underlying developmental difficulties, such as dyslexia, that may be unrecognised. There is some evidence that earlier reading difficulties may influence later mood and behaviour problems. Children that are particularly disruptive at school may be sent to Pupil Referral Units (PRUs), without necessarily receiving a full educational assessment to determine whether they have any underlying learning disorders that might influence their presentation of difficulties. Therefore there may be an increased prevalence of dyslexia in the PRU population, and in certain cases, if an underlying reading disorder in an EBD pupil was recognised and if suitable interventions were put in place, this could have a positive effect on reading ability and behaviour.

Dyslexia and Overlapping Disorders: Summary

There is a great deal of evidence that dyslexia frequently co-occurs with other specific learning difficulties, therefore a child with dyslexia may have difficulties in other areas in addition to difficulties with reading. A number of studies have reported that the occurrence of difficulties in areas such as attention, motor control, mathematics and language is significantly higher than that expected by chance. In the majority of these studies, investigators have generally focused on dyslexia and one other developmental disorder. The complexity of the situation is demonstrated in research by Kaplan, Dewey, Crawford & Wilson (2001), in which schoolchildren with reading disability (RD) and/ or ADHD were examined for a number of co-occurring disorders, including DCD, oppositional defiant disorder (ODD), conduct disorder (CD), depression and anxiety disorder. Results showed that 48% of this group met the criteria for one disorder, 27% had two disorders and 25% met the criteria for three or more disorders. Looking at those with RD, only 48% of this group had 'pure' dyslexia. These high rates of co-occurrence were found despite not screening for social skills or mathematics difficulties.

Reasons for this overlap of difficulties have been postulated. Twin studies have investigated the prevalence of developmental disorders in identical (monozygotic) and non-identical (dizygotic) twin pairs, and have reported evidence of some shared genetic influence in the co-occurrence of dyslexia and ADHD, aggressive behaviour, and mathematics (for example Gilger, Pennington and DeFries, 1992; Knopik et al, 1997; Willcutt et al. 2007). Richardson and Ross (2000) proposed that dyslexia, ADHD, DCD and ASD all have a biological basis, and suggest that fatty acid abnormalities could be implicated to some extent in these specific learning difficulties, and suggests this is a potential area for continued research. Some investigations have looked for causal relationships between different difficulties, and in some cases, researchers have attempted to explain the overlap of disorders by way of a shared cognitive deficit. For example Tiffin-Richards, Hasselhorn, Woerner, Rothenberger & Banaschewski (2008) reported evidence that a central executive functioning system could be a site of common cognitive deficit in dyslexia and ADHD, which may explain the high degree of overlap between the two disorders. Pennington (2006) rejected that a single deficit can adequately explain dyslexia, arguing that developmental disorders arise from the interaction of multiple risk and protective factors, which can be genetic or environmental, and comorbidity arises because of these shared risk factors.

A child with dyslexia may also be eligible for a co-occurring clinical diagnosis.
Difficulties associated with developmental disorders are often seen on a continuum, therefore a child with reading difficulties may show difficulties in other areas, such as attention and co-ordination, but not to the severity to meet the criteria for a diagnosis.

The reasons for the high co-occurrence of developmental disorders remains unclear, and it may be that reasons for overlap may be different for different children. However, there is a great deal of evidence showing dyslexia frequently to be associated with numerous other difficulties, and this has important implications for early intervention and multidisciplinary working.

Early intervention
Disorders of movement, attention and language can be recognised in the preschool years, before reading tuition begins, so it may be useful to identify children showing early deficits in these areas as being at risk of future reading difficulties. Screening for phonological skills may enable any deficits in this area to be recognised, thereby allowing early intervention to take place.

Multidisciplinary working
The need for multi-disciplinary, multi-agency input into the diagnosis and management of developmental disorders such as dyslexia is clear and is in line with the current emphasis on the importance of partnership working (Audit Commission, 1999; Department for Education (DfE), 1994; Department for Education and Skills and Department of Health (DfES/DoH), 2002; Department of Health (DoH), 1997; Department for Health, Department for Education, 2004; Health Advisory Service (HAS), 1995; House of Commons Health Select Committee, 1997; Welsh Assembly Government (WAG), 2002, 2004).

The Special Educational Needs (SEN) Code of Practice (Department for Education and Skills (DfES), 2001a; WAG, 2002) highlights the importance of agencies working in partnership with each other and suggests that partnership working should be based on a number of principles which include:

- early identification
- continual engagement with the child and parent(s)/guardian(s)
- focused intervention
- dissemination of effective approaches and techniques
- integrated high quality, holistic support focused on the needs of the child
- a flexible, child-centred approach to service delivery

The need for effective information sharing and communication between agencies both at management but also at practitioner level is also emphasized. This is particularly relevant in the assessment and subsequent

management of children with dyslexia. The document *Removing Barriers to Achievement*: *The Government's Strategy for SEN* (DfES, 2004b) specifically highlights the importance of partnership working to improve outcomes for children and young people with Special Educational Needs.

Research also highlights the importance of interdisciplinary working to recognise the full extent of the difficulties that a child is facing, and to put together suitable intervention strategies. Results from research can influence clinical practice, therefore it is important for future investigations to recognise that dyslexia as a 'pure' disorder is the exception rather than the rule, and investigating individuals with reading difficulties only, and excluding those with impairments in other areas may produce results that misrepresent what is observed in clinical practice. The prognosis for children with dyslexia worsens with increasing co-occurring difficulties; however an increased awareness of difficulties associated with dyslexia, early screening, and communication between parents/guardians, teachers and other professionals can allow a child's pattern of strengths and weaknesses to be recognised, which can subsequently inform practice, assisting individuals to reach their full potential.

VI. PSYCHOSOCIAL OUTCOMES

VI.i Educational Attainment Outcomes in Dyslexia/Learning Disorders

As dyslexia is a learning disorder, it is reasonable to assume that it would have some impact on the educational attainment of dyslexic individuals. Educational attainment focuses mainly on the overall level and quality of education achieved by dyslexics or individuals with learning disorders. Our review, which included studies comparing the educational attainment of dyslexics (in the United Kingdom, Europe, and the United States) to that of the general population produced mixed results.

According to some studies, dyslexia need not have significant negative effects on educational attainment. In a longitudinal study of Norwegian dyslexics, Undheim (2009) examined the persistence of the disorder as well as educational attainment levels. Individuals diagnosed with dyslexia at age 10 were followed up at age 16 and again at 23. Undheim found that the educational attainment of dyslexics was not significantly different from non-dyslexics. Similar results were obtained in another longitudinal study conducted in the USA by Seo, Abbott, and Hawkins (2008) in which the association between learning disabilities observed at age 10 and schooling and employment outcomes at age 21 and 23 was not significantly different from non-learning disabled peers after controlling for gender, ethnicity and socioeconomic status.

Not surprisingly, there is also evidence that significant differences do exist in the educational attainment of dyslexics and their non-dyslexic peers. Richardson and Wydell (2003) investigated the representation and attainment of dyslexics in universities in the United Kingdom, and found that for the year 1995 – 1996 of the approximately 1.7 million students enrolled 0.42% or 7, 305 identified themselves as dyslexics. Additionally these authors found that dyslexics were more likely to withdraw after their first year of study and were less likely to complete their programme of study. The proportion of students with no reported disability to obtain a first class or upper second class degree was 53. 6% compared to 43.9% for dyslexic students. Also Rojewski, (1999) found that individuals with learning disabilities reported lower graduation rates, were more likely to aspire to medium-to-low prestige occupations, and were less likely to pursue post-secondary education than their peers without learning disability. Additionally a study of the academic achievement of dyslexic boys who had attended an independent high school in New York (between 1 and 38 years after graduation) showed that outcomes varied as a function of the severity of dyslexia at school entry and of their achievement while at school (Finucci, Gottfredson & Childs, 1985).

Some explanations proposed by researchers for the lower achievement of dyslexics include negative socialization, cultural expectations and fewer real or perceived occupational opportunities (Rojewski, 1999). To summarise, although there are dyslexic individuals or groups whose academic achievements are equal to their non-dyslexic peers, a large number of dyslexics is underachieving. Additional factors that may impact on educational attainment include socio-economic status, the severity of the disability and level of co-existence with other specific learning difficulties having an additive effect.

An encouraging finding, however, is that educational attainment of dyslexic students can be comparable to that of their peers if they are provided with the necessary educational support (Reed, Kennett, Lewis, Lund-Lucas, Stallberg & Newbold, 2009). Thus, although dyslexia can have a negative effect on the level and the quality of educational attainment of dyslexics, these can be eliminated or at the least significantly reduced with appropriate attention and resources, enabling dyslexics to obtain educational qualifications that are equal to their peers.

VI.ii Psychosocial Consequences of Dyslexia/Learning Disorders

In addition to the cognitive deficits associated with dyslexia and other learning disorders, a number of adverse psychosocial consequences may also be associated with developmental disorders. Some of these consequences include mental health problems, behavioural difficulties, and low self-esteem. In general, research indicates that individuals with learning disabilities are at increased risk for mental health problems such as anxiety and depression. Carroll and Iles (2006) found higher overall levels of anxiety as well as higher academic and social

anxiety among British dyslexic students. Undheim and Sund (2008) found higher depressive symptoms, more school stress and mental health problems among Norwegian adolescents with self-reported reading difficulties. The extent of this increased risk is highlighted in a Canadian study which found that people with learning disability were two to five times more likely to report mental health problems than the rest of the population (Wilson et al., 2009).

A number of studies have also reported low levels of self-esteem among individuals with learning disabilities. Riddick, et al. (1999) found that dyslexic adult students reported lower levels of self-esteem than their peers. Similarly adolescents reported lower levels of self-esteem than controls in the study by Undheim & Sund (2008). Lower levels of self-esteem have also been found in younger children. Humphrey (2002) found that dyslexic children in mainstream schools as well as in schools for children with specific learning difficulties reported lower levels of self-esteem than their non-dyslexic peers.

Evidence of behavioural difficulties (including emotional symptoms, conduct problems, hyperactivity, peer problems and social behaviours) is provided in a longitudinal study investigating the existence of behavioural, emotional and social difficulties in children with specific speech-language difficulties (Lindsay, Dockrell, & Strand, 2007). In this study both parents and teachers reported higher levels of behaviour difficulties for children with specific speech-language difficulties, which are often associated with literacy problems. Parents also reported higher levels of delinquent behaviour in adolescent poor readers in another study which examined the severity of emotional, behavioural and attention problems among adolescent poor readers and controls (Arnold et al., 2005). Similarly, in the long-term follow-up of Snowling's sample of children at familial risk of dyslexia, the parents of those now adolescents who continued to experience reading difficulties reported their children to have higher rates of emotional difficulties, while the adolescents rated themselves as poorer in scholastic achievements than their non-dyslexic peers (Muter & Snowling, 2009; see also Chapters III and V).

Implications for Diagnosis, Assessment and Support

To summarize the existing research indicates that individuals with dyslexia and other learning difficulties are at increased risk for a number of psychosocial difficulties. It is therefore necessary to consider these and not only literacy difficulties in the assessment and provision of support for these individuals. The problems experienced by persons with learning disorders may require the collaboration of educational and mental health professionals, including support in the management of anxiety and depression, in order to fully provide appropriate services for these individuals. This need is augmented by the levels of comorbidity or co-occurrence associated with dyslexia such as ADHD and ASD.

VII. SCREENING

Criteria for screening

Screening is generally a quick, low cost, test suitable for widespread use, which is administered by trained, but not specialist, personnel. Screening is used to identify children at risk of dyslexia, not to diagnose reading difficulties (therefore it does not replace full assessment of a child's special educational needs). Screening, by definition, is given to all members of a population, but may be given by the teacher to children identified as having difficulties. The motivation behind the use of screening tests, is usually to intervene to improve outcomes on the basis of brief skills evaluations.

Early screening

Some excellent theoretical studies have been undertaken in a range of countries investigating precursors of literacy in longitudinal studies, which identify in 6 and 7 year olds which skills at 4 and 5 are the best predictors of later success (Caravolas et al., 2001; Muter et al, 2004; Gijsel et al, 2006; Heath and Hogben, 2004; Marx and Weber, 2006; Puolakanaho et al, 2007; Wood et al, 2005). In alphabetic languages such as English there is robust evidence that these predictors are letter knowledge and phoneme awareness (Byrne & Fielding-Barnsley, 1989; Caravolas et al., 2001; Muter et al., 2004). In turn, phoneme awareness is predicted by pre-school measures of syllable and rhyme awareness (correlated with vocabulary level) with a small contribution from speech awareness (Carroll et al, 2003). It follows that screening measures should focus on the assessment of phonological awareness, letter knowledge and to a lesser extent on vocabulary.

Issues in the delivery of screening

One advantage of early screening is that it moves away from the 'wait to fail' approach that formerly characterized diagnosis in dyslexia, and tries to identify problems early on. More critically, to be worthwhile, screening needs to be followed by fuller assessment of a child's learning needs and appropriate intervention.

Screening can take a number of forms: screening procedures can be based on teacher observation. There is good evidence that teachers can make valid judgments regarding the progression of children though the early phases of literacy development (for example through the phonic phases in the Letters and Sounds programme, DCSF 2007); and supplementing teacher observation with simple tests of letter knowledge and spelling may provide effective ways of screening. There are also batteries of screening tests in use in schools which follow a more formal procedure. However it needs to be acknowledged that screening is only the first step in an assessment process.

Although screening tests should be objective, reliable and valid, they also need to be quick, and this reduces their reliability. Two key aspects for any screening test are the 'hit' rate (the percentage of 'really at risk' children who are screened as 'at risk') and the 'false positive' rate (the percentage of 'really not at risk' children who are screened as 'at risk'). An ideal screening test would have 100% hit rate and 0% false positive rate, but a more realistic target would be more like 85% hits and only 20% false positives. No screening test is 100% accurate; most tests identify some children as at risk who will go on to be good readers as well as missing some children who go on to have difficulties. On average screening tests are 75% accurate. In this light, data from screening tests need to be interpreted with caution, and continued monitoring of children found to be 'at risk' is required. Interestingly, it is much easier to predict which children are going to have strengths in literacy rather than those who are at risk. It is particularly important that tests used for screening are set at the right level for the age group, and normed on a representative population of children.

Effective screening tools

The SEN Code of Practice for Wales (2004) builds on the UK Code of Practice, 1994, and requires schools to identify children at risk of reading failure as early as possible. In response to this, a number of tests have been developed in the UK (*CoPS* - Singleton 1995; the *Dyslexia Early Screening Test* (DEST) - Nicolson and Fawcett 1996, the *Dyslexia Screening Test - Junior* (DST-J) – Fawcett and Nicolson 2004; *PhAB* (Phonological Assessment Battery) - Frederickson, Frith and Reason 1997; and the *Phonological Abilities Test* - Muter, Hulme and Snowling 1996)). There are clear differences in the way these tests are used.

Given the intended use of screening tests as the first stage in the support process, the most useful screening tests are designed to quantify strengths as well as weaknesses. One test that has been developed for early years screening (4.5 to 6.5 years) is the DEST (Nicolson & Fawcett 1996, 2004). It is a 30 minute nationally normed test intended for use by teachers, and comprises sub-tests selected to give positive indicators of likely reading failure. The DEST leads to an 'at risk' index, together with a profile of strengths and weaknesses indicative of the appropriate types of support. The DEST was used as one tool to screen children in an intervention study (Nicolson, Fawcett, Moss, Nicolson, and Reason, 1999), and gave both the best 'hit rate' (88%) for the 'problem readers' and also the best discrimination between children who made progress and those who did not. However, subsequent studies (e.g., Whiteley, Smith & Connors, 2007; Simpson & Everatt, 2005) have reported that only one or two of the subtests of the battery were useful in identifying children at risk, and noted that tests of letter knowledge alone could be used to achieve these predictions.

There is also a number of computer based screening tests for use with young children, for example Turner and Smith, 2004 and the Lucid CoPs profiling system. Turner and Smith for ages 5-16 includes measures of verbal and non-verbal IQ, but no phonological tests. CoPs which forms part of a suite of phonologically based cognitive screening tests was designed by Singleton. Predictive validity for CoPS from 5-8 years was similar to DEST overall, but for CoPS there were false negative rates of 16.7% with false positive rates of only 2.3%. This means that 16% of the group who later had difficulties were not identified. Marks and Burden (2005) evaluated the prototype CoPS and queried whether this could function as a standalone screening test, but Singleton (2009) has stressed that it was meant to identify strengths and weaknesses to assist in the identification of dyslexia and other learning disabilities, and to create appropriate individualized teaching.

There are several advantages for computer based screening, which places fewer demands on teachers and teaching assistants than paper based tests. On the other hand, many teachers prefer to administer tests themselves because they gain so much information from how a child completes the test, which itself forms part of the child's profile. Moreover, there may be a potential for error when young children work on computers, because they may not understand the demands of the task, and the computer cannot identify this, whereas a teacher may be able to do so. However in the future, the development of sensitive and informative computer programmes may eventually provide a way forward for 'mass' screening.

Screening in older children and adults

Screening tests for older children and adults include measures of literacy, and should include both speed and accuracy. If children have severe problems in basic reading skills, it is easy to see that they need support, but many children with dyslexia can read well enough to scrape through a standardized untimed test, but are very slow and not at all automatic in their skills, which means that they have great difficulty in remembering what they have read for long enough to understand it. Examples of screening tests for this age group include the LASS junior computer screening from Chris Singleton (Thomas, Horne and Singleton, 2000) and Dyslexia Screening Test-Junior, (Fawcett and Nicolson, 2005). For the limitations of the latter, see Barth et al. (2010).

Summary

The overall aim of the screening tests is to ensure that the majority of children receive support to reach their potential, thus ensuring that children do not experience long periods of failure before support is provided. Best practice would ensure that the majority of children did not need extensive support after the age of 8, cutting down on the need for statementing, and ensuring that resources can be targeted to dyslexic children with the most intractable difficulties. There is considerable support for empowering teachers to learn about the alphabetic principle, and to train them to assess – by screening – children's mastery of it. The high rates of comorbid difficulties, which may also be measurable at the start or prior to schooling, suggest that an effective approach should include screening the other learning modalities to identify those children at serious risk of failure. To meet this objective in the Welsh linguistic context, more Welsh language tests are needed to address these problems. The recently published Rose report (Rose, 2009) does not recommend large screening batteries, as these may not be necessary or effective. Instead the report advocates that teachers be trained to identify children failing to acquire the alphabetic principle as early as possible, and to then move to a stage of assessment for learning. It is advised that intervention need not wait for diagnosis, but should start as soon as 'screening' identified a problem.

VIII. ASSESSMENT OF DYSLEXIA

Diagnosis

Until recently, the major developmental disorders were traditionally defined at least partly in terms of a discrepancy between the child's achievement of one or more specific abilities, such as reading and spelling, and that expected on the basis of the child's measured intelligence. For example, according to The World Federation of Neurology (1970), dyslexia was defined as "a disorder manifested by difficulty in learning to read despite conventional instruction, adequate intelligence, and sociocultural opportunity" (Critchley, 1970). Some o the current definitions still contain overtones of this 'discrepancy view', although the current view sees developmental disorders, including dyslexia, as existing on continua of severity and complexity, neither of which is directly contingent on IQ (see also Chapter IX). The discrepancy approach raised three major concerns: the limitations of psychometric intelligence tests such as the WISC and WAIS; the potential oversight of dyslexia among poor readers without discrepancy (that is, those who have weaknesses in both literacy and general cognitive ability); and, of greatest importance theoretically, is the unclear differentiation between poor readers with and without discrepancy across various components of reading skill (Ellis, McDougall, & Monk, 1996; Lyon, Shaywitz, & Shaywitz, 2003; Morris et al., 1998; Siegel, 1989; Stanovich, 1993; Stuebing et al., 2002).

An educational worry arising from the discrepancy-based diagnostic approach is that a child of above average intelligence, who is reading at a level appropriate for her chronological age (but not above average, in line with expectation), may be identified as in need of support, while a weaker reader failing to meet the discrepancy criterion may not be eligible. Within the context of limited resources, this approach makes more difficult the decision about which child with additional learning needs should be prioritized for additional support.

Criteria for assessment

Traditionally dyslexia has been diagnosed by using an IQ test, and by a series of standardised tests of performance in literacy, at least of single word reading, and spelling, as well as of text reading and writing. Increasingly, however, these basic batteries are being supplemented by a range of tests assessing the skills and abilities that are directly linked to, or frequently associated with dyslexic difficulties, including oral language skills, measures of arithmetic ability, attention, and praxis.

Effective assessment tools

Various organizations (BDA, BPS, PATOSS) provide lists of recommended assessment tools for particular populations and testing situations (see the Summary Tables A2, A3, A4 & A5 in Appendix A). The Summary Tables in Annex A contain concise adaptations of the materials described in the source materials; for the full descriptions of these materials, the reader is referred to the source web sites (web addresses provided below each Summary Table in the Appendix). A note of caution for users is that some of these tests have poor predictive validity for correctly identifying those individuals who are at risk.) An assessment based on IQ is not sufficient to diagnose dyslexia, and educational psychologists, as well as specialist teacher assessors need to include additional standardised tests of reading accuracy, reading speed, phonological ability, spelling, and writing. Recently, teachers with a certificate of competence in educational testing from the British Psychological Society have been allowed to assess children for dyslexia, using tests which are not 'closed', that is, with tests that are not limited to educational psychologists. A selection of tests which have been agreed as appropriate for the assessment and diagnosis of dyslexia are detailed in Appendix A, Table A6.

Issues in assessment

Traditionally, children who have not been diagnosed as dyslexic have not been entitled to extra support. This is the crux of the arguments about definition. It is often difficult within the education system to identify which child is most in need of support, and funds are not always available to provide support for everyone with additional learning needs.

Controversy over dyslexia continues with some psychologists claiming that dyslexia is a myth, and that there is no need to differentiate among poor readers, because they all need the same type of support. On 18th December, 2009, the Science and Technology committee issued a report that concluded that the *Rose Report* had been driven by the dyslexia lobby, and that the government should stop talking about specialist dyslexia teaching,

because children diagnosed with dyslexia and children who struggle with reading for other reasons, are taught how to read in exactly the same way. This statement assumes (incorrectly) that dyslexia is simply poor reading, and that there are no differences between dyslexic children and, for example, those children who have problems with comprehension.

The evidence suggests that all children should receive early preventative support, because this is both effective and cost-effective. The debate continues as to whether dyslexia is a separate condition or part of a continuum, but there is accruing evidence for a genetic basis and differences in the brain in individuals with dyslexia (see Chapter III). The Science and Technology report (Science and Technology Committee,2009 HC44) recommends that the strongest evidence-based approach to this debate will be to compare and contrast dyslexic children and non-dyslexic poor readers. Such research is already under way, with attempts to tease apart the complex relationships among contributors to reading difficulty such as broader oral language impairments, attention deficit, motor and coordination problems, and sensory difficulties (see Chapters III and V).

Possible Impact of Research Outcomes to Current and Future Policies

If children with potential risk factors could be identified in reception, in nursery or earlier, help could be provided for them from a young age, when intervention may be most effective, much like the Flying Start initiatives currently operating in Wales.

There is a real opportunity to make sure that dyslexic children are not disadvantaged by their differences. The promise of this new approach is that children with developmental disorders can be profiled, which will allow targeted IEP's to be created for a range of difficulties, which could potentially alter the course of development for these children, and impact on the number of school leavers and adults whose skills remain impaired (cf. the Public Accounts Committee report, 2009).

IX. INTERVENTIONS CURRENTLY ACCEPTED AS BEST PRACTICE

In this chapter, material is drawn from a range of sources, including summaries (e.g., Fawcett, 2002), reviews (e.g., *What works for pupils with literacy problems* (Brooks, 2007); *Review of interventions for the Rose Report* (Singleton, 2009); meta-analyses by the National Reading Panel (NRP, 2000); and *What works Clearinghouse* (Slavin, 2009b), as well as a systematic review of the current literature.

Criteria for inclusion

The aim was to adopt stringent criteria for acceptable research, with the inclusion mainly of studies undertaken with children with diagnoses of dyslexia or language disability, which met the 'gold standard' of randomised controlled studies including pre- and post-tests with standardized tests. In keeping with the aim of the Welsh Assembly Government's Rapporteur Group's report to provide support by Year 2 at the latest, literature on early intervention in 'at risk' populations was also covered, and the costs and benefits of this approach were considered. The original studies presented in this section were published in peer-reviewed journals.

Controlled studies: The issues

The gold-standard experimental design for evaluating interventions is the double blind placebo controlled study, taken from the medical field where it is widely used to evaluate the effectiveness and safety of new drugs. A double blind approach means that neither the experimenter, the child, the teacher, nor the family know which intervention (target or placebo) the child is receiving, or what therapy is being tested. Studies that are double blind overcome any tendency for performance to improve simply because the child or the experimenter expects this. In some studies, a cross-over technique is used, in which half of the children receive the placebo (or alternative intervention) in the first set of trials and, if the intervention is effective, they receive the intervention in the second set. This is held to be ethically sound because no one is deprived of an intervention thought to be beneficial. This approach is relatively easy within a medical setting, but is less easy to adhere to in an experimental or school setting (Haslum, 2007).

IX.i Background

Most educationalists would agree that reading for meaning is the ultimate aim of reading instruction. However, dyslexia affects above all children's ability to decode, recognize, and spell single words, rather than text comprehension per se (Bishop, McDonald, Bird, & Hayiou-Thomas, 2009; Bishop & Snowling, 2004), and therefore much of the research in the area has focused on the ability to improve single word reading and spelling, and to a lesser extent directly on text reading (e.g., Hatcher, Hulme, & Ellis, 1994; Hatcher, Goetz, et al., 2006; Torgesen et al., 2001). There is solid evidence that reading ability can be improved through targeted intervention programmes, although typically it is easier to improve skills in a normal reader, or an 'at risk' beginning reader, than it is to help an older, severely dyslexic child. Prior to presenting the research review, however, an explanation is provided of the techniques that allow comparisons between different studies to be made.

Measuring improvements

A statistic used to estimate improvements in intervention studies is called an '*effect size'*. This allows comparisons to be made between different studies, and to assess the magnitudes of improvements resulting from different interventions. Effect sizes are worked out by taking the mean performance of the control group from the mean performance of the intervention group, and dividing this by the standard deviation of the two groups. This allows any differences between the two groups to be measured, taking into account the variability within the group at the start. Note that this statistic does not reflect the amount of time that was needed to achieve the effect (this will be discussed later under the heading cost-effectiveness).

An effect size of 0 means that the treatment and control groups are the same. An effect size of + or – 1 means that the intervention group is 1 standard deviation better/worse than the control group. In terms of the statistical significance of effects sizes (expressed as *d*), *d* = 0.20 is considered low, *d* = 0.50 is moderate and *d* =

0.80 is high (Cohen, 1988). Sample size affects the reliability of effect sizes such that larger samples produce more reliable results. To illustrate how difficult it can be to make any difference with an intervention, it is useful to understand that even well designed interventions based on 35 hours extra teaching over a year using a well-tried method, the Orton-Gillingham approach, can achieve an effect size of as little as 0.04 improvement in reading in comparison with a control group who received normal teaching. An analysis of the 100 effect sizes derived from the NRP's (2000) meta-analysis showed that effect sizes greater than 0.80 were found in 32 studies and effect sizes of 2.0 and above were comparatively rare (6/100).

Ratio gain

Many studies use ratio gain as a measure of improvement when there are no controls and children are used as their own control. This is measured by a gain in performance in the group relative to their own expected achievement. Development at a 'normal' rate gives a ratio gain of 1, but if children have fallen behind it is very difficult for them to catch up with their peers, and a ratio gain of 1.4 is needed to be meaningful (Brooks, 2007) while 2.0 represents good evidence of improvement. Singleton (2009) noted that interventions with populations drawn from the 77 UK special schools for dyslexia have not been as successful as hoped; however, children attending these schools often have severe and long-standing problems, which are more difficult to remediate, and therefore ratio gains of approximately 1.0 should be seen as progress.

The issues

One of the difficulties in any training programme is that training may lead to improvements in the area which has been trained, but it may not generalize to reading ability overall. Also, it needs to be ascertained that observed gains do not merely reflect a *Hawthorne effect* of the greater interest taken in the child. Another challenge is to demonstrate improvements in terms of *standard scores*, because these take age into account; any gains in standard scores reflect a 'faster than normal' rate of development. Thus, it is important to demonstrate that an intervention produced an improvement from pre- to post-intervention on a particular reading measure, but also that it went some way to 'closing the gap' between the dyslexic child's performance and that of his/her age peers, as measured with standardized scores. It is a notable achievement that certain well-designed interventions have lead not only to generalized improvements in reading accuracy, comprehension, *and* spelling skills, but they also produced significant gains that were measurable in standardized scores (e.g., Hatcher, Hulme & Ellis, 1994; Hatcher, Hulme, et al., 2006; Torgesen et al., 2001). Notwithstanding these successes, there are individual differences among children in 'responsiveness to intervention', and remediating reading difficulties in some severely impaired readers has proven difficult, even with well evaluated traditional interventions (Torgesen, 2000). Reading researchers are now turning their attention to better understanding these children's difficulties and learning needs (Al Otaiba & Fuchs, 2006; Duff et al., 2008). Below we summarize some of the important findings in reading intervention research, with a focus on several critical questions for the development of programmes for best practice. These include:

- Are there significant differences between training programmes and what is the best type of training?
- What age is likely to be the best to intervene?
- Does it matter how intelligent the children are, or can the same approach be used with children of all types?

In addition, we present a framework which emphasises not only effectiveness but also cost-effectiveness

IX.ii Types of Training

It is now well established that phonologically-based instructional methods are highly effective for teaching the foundational literacy skills (e.g., decoding, recognizing and spelling single words) to typically developing children, as well as for remediating the difficulties of struggling readers (e.g., NRP, 2000; Torgerson, Brooks, & Hall, 2006). These methods, when properly delivered, are related to growth not only in word-level skills, but also in reading comprehension. Below a brief description is presented of the two main types of phonological training approaches.

i) Phonological awareness training

Phonological awareness training teaches the ability to consciously manipulate and make judgments about phonological units (i.e., speech sound units) in oral language tasks. As reviewed in Chapter III, among phonological processing indices, phonological awareness in general, and *phoneme awareness* in particular, is a core early predictor of later achievement in reading and spelling (e.g., Caravolas et al., 2001; Muter et al., 2004). Moreover, weakness in phoneme awareness has been found to be the core deficit for most children with developmental reading difficulties (Torgesen, 2002; Vellutino et al., 2004). It is therefore not surprising that much research has focused on evaluating the effectiveness of phonological awareness training in improving literacy outcomes, in particular of children at risk of reading failure and in those already diagnosed with developmental dyslexia.

The positive impact of phonological awareness training on literacy development was confirmed in two major meta-analyses (Bus & Van IJzendoorn, 1999; NRP, 2000). The NRP's (2000) meta-analysis of 96 studies carried out in the US reported positive effects on reading accuracy (*d* = 0.53), spelling (*d* = 0.59), and even on the more distal skill of reading comprehension (*d* = 0.34). Both reviews also showed that phoneme awareness training is most effective when associations between sounds and letters are also explicitly taught (*d* = 0.67, about twice as effective as training without letters). Interestingly, research seeking the most effective *phoneme awareness* training approaches has revealed that most tend to be equally effective (e.g., Torgesen, 2005). For example, Torgesen et al. (2001) compared the effectiveness of the *Lindamood Phoneme Sequencing Programme* in which primary emphasis was on articulatory/phonological awareness training and single word reading, and, an *Embedded Phonics* programme that prioritized text reading along with phonics and phonological awareness training. The study yielded very impressive results such that both groups had improved their reading from the severely impaired range to the low average range after an intensive 8-week intervention of some 68 hours of tuition. Torgesen (2005) also compared interventions targeting primary school children with moderate to severe dyslexic difficulties. Across interventions, trained children made substantial progress in word reading and reading comprehension on the order of 0.20 standard deviation scores per hour of tuition; but again, no one method produced significantly greater gains than its competitors. This pattern was echoed in a meta-analysis by Torgerson and her colleagues (Torgerson, Brooks, & Hall, 2006) who found that phoneme awareness training methods have positive effects on reading gains, and they tend to produce no significant differences between them; it is the inclusion of phoneme awareness training components as such, along with systematic phonics instruction (see below), that leads to the most successful outcomes.

ii) Phonics training

The term *phonics* is usually reserved for methods of teaching reading and spelling in the classroom. Clearly, phonics approaches have a great deal in common with phoneme awareness training (especially when phoneme-letter associations are also taught), however, the phonics literacy curriculum goes beyond training awareness of speech sounds in isolation, and applies these skills to early word and text reading as well as to spelling. The optimal approach to teaching phonics has been a topic of debate in the English-speaking world for many years with recent distinctions being made between methods such as Analytic, Synthetic, and Embedded Phonics systems (Torgerson et al., 2006).

Analytic phonics aims to help the child learn grapheme-phoneme correspondences, not through explicit instruction of these units in isolation, but rather by deduction on the basis of exposure to sets of words that share grapheme-phoneme units (e.g., *h*at, *h*en; ti*n*, pe*n*, etc.). In *Synthetic phonics* the letter-sound associations are explicitly taught in isolation (e.g., *t*-/t/, *e*-/ɛ /, *n*-/n/, *a* - /æ/), and then the alphabetic principle is taught through phoneme blending activities (e.g., *t*, *n*, *e*, and *a* can make: *ten*, *net*, *tan*, *ant*, etc.). This is currently the major approach favoured in the UK, but interestingly a review by Torgerson et al. 2006 concluded that analytic and synthetic phonics approaches yielded comparable results among mainstream Key Stage 1 pupils. The *Embedded phonics* approach links phonics instruction more directly to various reading and writing activities, and is less structured and systematic.

In the meta-analyses examining different phonics approaches, the distinction was made between *systematic* (explicit, organized, sequenced), *unsystematic* (incidental, unstructured) and no phonics instruction (e.g., NRP, 2000; Torgerson et al., 2006), and clearly the greatest benefits were generated by systematic phonics approaches. Several recent re-analyses of the NRP's database, which controlled for effects of other non-phonics instruction, further confirmed the effectiveness of systematic phonics (Camilli, Vargas, & Yurecko, 2003; Stuebing, Barth, Cirino, Francis, & Fletcher, 2008), however, it has been found to be most effective when delivered in a 'broad literacy curriculum' that includes group reading and writing activities, and meaning-led literacy activities (Torgerson et al.,
2006). In sum, phoneme awareness training along with systematic phonics teaching have proven effective in the early school years both in mainstream teaching and in the prevention and remediation of reading difficulties.

Which is best?
For reference, a summary table has been provided in Appendix A, of intervention studies, ordered by effect size and by type of school population(Table 7A , that were covered in the various reviews discussed above. In Table 8A, the same analyses are presented for ratio gain. Amongst the most successful interventions in the UK are a series of studies by Hatcher and colleagues, which deliver a combination of phoneme awareness, phonics (the *Sound Linkage* programme), and broader reading and writing activities (Hatcher et al, 1994, Hatcher, Goetz, et al., 2006, Hatcher, Hulme, et al., 2006). This programme was recognized by Troia (1999) for its methodological rigour, and has a well established efficacy (e.g., Bowyer-Crane et al., 2008; Hatcher, Goetz, et al., et al., 2009b/2006). A series of 10-hour phonics and fluency interventions using a scheme known as *Interactive assessment and teaching*, a photo-copyable scheme developed by Reason and Boote (1994), was also found to be effective (Nicholson, Fawcett, Moss, Nicolson, & Reason, 1999). In answer to the above question, however, no one variant of phoneme awareness and systematic phonics is clearly superior; it is their principled and well-ordered combination and embedding within a broader literacy curriculum that yields best outcomes.

Tips for Best Practice in Reading Intervention for Dyslexic Readers
(Brooks, 2007; Torgerson et al., 2006; Torgesen, 2002)

Relative to the general curriculum, programmes should include:
- greater explicitness and direct teaching of skills
- greater intensity of instruction
  - in frequency of teaching
  - in more individualized attention or small group teaching
- more academic and emotional support
- **intervention that supplements and does not replace general classroom literacy instruction**

IX.iii Theoretical and Practical Issues

At what age should we intervene?
With respect to phoneme awareness training, the answer to this question is reliably '*the earlier, the better*'. The NRP's (2000) and Bus and van IJzendoorn's (1999) evaluations revealed that phoneme awareness intervention is most effective when delivered to 'at risk' preschoolers; the impact of this training on reading declines for children with known difficulties as they grow older (grades 2-6, ages 7). The results are less clear for reading (phonics) intervention programmes. Some studies have found intervention to be more effective among younger than older primary school children (Denton, Fletcher, Anthony, & Francis, 2006; Wise, Ring, & Olson, 2000), but others – comparing slightly older groups of children have found no age differences (Lovett & Steinbach, 1997; Schneider, Ennemoser, Roth, & Kitspert, 1999). One possibility is that the effect of age on responsiveness to reading intervention depends on the age bands being assessed. This issue is under further research. Consistent with this,

studies in the UK have confirmed that younger children who have received intervention are more likely to 'accelerate' to keep pace with their peers than children at junior school level (Nicolson & Fawcett 1999, Fawcett & Nicolson, 2000). Together, these results emphasize the importance of early identification of risk factors and of early intervention.

Does intelligence matter?

The issue of intelligence is emerging as an important one because

a) until recently, it has been central to the identification of dyslexia (based on the 'discrepancy definition' (Rutter & Yule, 1975)), and
b) the recent findings reveal a weaker relationship between IQ and reading skills than was previously assumed, and
c) the characteristic phonological awareness deficit is present among poor readers regardless of IQ level (Fletcher et al., 1994; Stuebing et al., 2002).

With respect to the important question of whether IQ is predictive of responsiveness to reading intervention, the results to date are not consistent. Some studies have reported a significant relationship (Berninger et al., 2002; Foorman, Francis, Fletcher, Schatschneider, & Mehta, 1998) and others haven't (Hindson et al., 2005; Torgesen & Davis, 1996). These mixed results have been found specifically in the relationship between IQ and growth in phonological awareness and word-level skills. A more consistent picture is emerging for a significant relationship between IQ and responsiveness to reading comprehension training, however, the effect seems rather small, accounting for 1% to 3% of the variance in responsiveness (Stuebing, Barth, Molfese, Weiss, & Fletcher, 2009).

An important implication for educators is that the current evidence gives no clear reason for excluding children with lower IQ from the types of interventions currently held to represent best practice, either in word-level reading and spelling skills or in reading comprehension. The evidence also strengthens the rationale for moving away from the 'discrepancy definition' of dyslexia.

Cost effectiveness

It is important to make sure that intervention is not only effective, but is also cost effective (for overviews see Fletcher-Campbell, 1996; Saunders, 1998). Cost effectiveness can be estimated based on the amount of benefit conferred by the intervention, over and above the regular teaching provision (i.e., the *added value effect size*), and on the number of hours of teacher input per child. One important finding in this respect is that intervention provided in small groups can be just as effective as working with children individually, particularly with younger and less severely impaired children. Cost-effectiveness will also vary depending on whether 'specialist' teachers are used or whether the approach involves support by non-specialists. In costing *support*, the amount of time the intervention takes is multiplied by the number of children in the group and by the number of weeks the intervention lasts. This gives a measure of 'dedicated' teacher time per child. Improvements are measured in terms of the improvement in skills, divided by the amount of teacher time needed to make this change.

On this basis, some of the more widely publicised approaches such as Reading Recovery, are disappointing in their cost-effectiveness index because they are based on many hours of teacher input. The cost-effectiveness of systematic phonics approaches should be evaluated, with long-term follow-ups to check that the effects have persisted.

Summary

It is clear that children's skills can be improved with phoneme awareness and systematic phonics methods that are embedded within a broad literacy curriculum; and, the benefits are greatest for younger children. Wherever possible, children who are 'at risk' should be identified in the preschool and early school years, and they should receive well-structured and systematic intervention. This early support would 'accelerate' the literacy skills of the majority of the 'at risk' children, and possibly reduce the severity of their impairments. This in turn would allow many children to keep pace with their peers, and others to move into a category of milder deficit. This should not only impact favourably on educational costs but also improve standards within education in Wales. However, it should be borne in mind that a constant number of children with severe and profound difficulties will not respond well to treatment. Often, such children fail to improve despite the early years input and they continue to need specialized help in school. They require higher and more prolonged levels of resources for their educational provision. Nevertheless, the numbers of these children could be significantly reduced by early intervention, thus ensuring that funding is concentrated on those children with entrenched difficulties.

X. COMPLEMENTARY INTERVENTIONS

What is meant by alternative or complementary approaches?
Usually, 'complementary approaches' refer to those approaches which are (a) very individual and (b) not available in the mainstream classroom. Schools tend to use mainstream approaches which have been tried and tested over a period of time or are recommended by government reports. For example the UK *Rose Report* (Rose, 2007) suggested that schools should be using synthetic phonics following a number of research studies that had been conducted which highlighted the merits of this approach. In the USA the *No Child Left Behind Act* also advocated a number of established practices (see http://www.ed.gov/nclb/overview/intro/ reauth/successstories/index.html). As noted in Chapter IX, not all children respond equally well to even the best attested interventions, and no therapy has yet proven to be the magic bullet, despite the development of costly long term studies by the National Institute for Child Health and Human Development (NICHD) in the USA to help children with dyslexia. One limitation of current phonics-based interventions is they may not generalize to *fluent* reading (e.g., US NRP, 2001b). It is against this background that the alternative therapies in this section should be evaluated. It is important to be aware that some of the interventions below reported have been more stringently evaluated than others.

X.i Movement Approaches

The Dore programme
According to the Company website, this is a drug free programme of special exercises, guidance and coaching used to treat learning difficulties. It includes the use of a wobble board (to help with balancing), bean bags (to help eye tracking and coordination), gym ball and eye chart. It is said to be designed to improve cerebellum efficiency through unique exercises and to train the brain to speed up and automate information flow (http://www.dore.co.uk/programme/science.aspx). The Dore approach has largely been based on the theory of cerebellar deficit of dyslexia (Nicolson and Fawcett, 1995, 2001), which claims that the problems in learning to read are part of a brain-based problem in learning to become automatic in any skill, originally identified in balance (Nicolson and Fawcett, 1990).

This has been arguably the most controversial approach over recent years, based on a published controlled study with a cross over design (Reynolds and Nicolson, 2007). The children tested showed mild deficits on a screening test, and they were matched on their overall performance on that test, rather than their reading age. This study as well as a follow-up were found to be methodologically flawed and were at the centre of considerable controversy. The Dore approach, as originally instantiated, was expensive to deliver, and promised to continue training until the children and adults involved were 'cured' in terms of their balance and eye movements. Many of the children attending had complex problems, they had already received traditional intervention without much success, and their treatment was lengthier than Dore had originally anticipated. In 2008, Dore ran into financial difficulties, closing his centres. Recently, a centre has reopened, although the approach remains controversial, especially with respect to its validity (Bishop, 2007).

Brain Gym
According to the Company website, Brain Gym is a part of the Educational Kinesiology programme developed by Dennison and involves a group of body-based movement tools designed to prepare the brain and body for learning and life (www.braingym.org.uk/pdfs/bluepack.pdf). Educational Kinesiology was developed as a programme of body-based tools to assist learning challenges, particularly reading. Brain Gym involves a series of 26 movement-based activities designed to assist learners with the physical skills for learning (reading, writing, concentrating and organizing), (http://www.braingym.org.uk/faq/faq.htm). Brain Gym is a good example of an alternative approach that has become very popular. The approach focuses on the importance of dominance and laterality and, particularly, the influence of dominance patterns on learning (Dennison, 1981; Dennison & Hargrove, 1985). Information provided on the official website reports a range of academic studies, many of them published in the *Brain Gym* journal, that provide evidence of the effectiveness of the Brain Gym programme. However, a recent review of the research in the area (Hyatt, 2007) concluded that both the theory and the experimental evidence provided do not support the current wide use in the school environment.

X.ii Unevaluated Approaches

The Raviv method

According to the Company website, this is an exercise based programme designed to improve the coordination and synchronization of the neural systems in the brain and consists of two main stages; preparing the brain to learn and correcting and improving learning skills (http://www.thelearningsociety.com/index.php?option=com_content&view=article&id=19&Itemid=26).

There are no published studies yet on the Raviv method, although materials on the website suggest an 80% improvement in 3 months for 10 children with severe problems in Newport Wales, with improvement continuing after 9 months untreated. The largest improvements were found in hand-eye co-ordination and speeded writing, but there was also evidence of improvements in reading, spelling and maths. However, there is no evidence to date from controlled studies reported in peer-reviewed journals to provide support for this.

X.iii Visual Approaches

Scotopic Sensitivity/ Meares-Irlen

Scotopic sensitivity, which is more commonly referred to as Meares–Irlen Syndrome, refers to the presence of a visual defect that can be related to difficulties with light source, glare, wave length and black and white contrast. It is usually treated with coloured tints either acetate overlays or tinted lenses (Singleton, 2009). The term was first used in 1983 when Irlen proposed that tinted glasses would improve the reading ability of dyslexic children in a paper on Scotopic Sensitivity Syndrome presented at the annual meeting of the American Psychological Association. The treatment became popularised and sensationalised before there was time for sufficient control studies to be carried out to verify the claims (Silver, 2001).

In a randomised controlled trial of the effect of coloured overlays on rate of reading in children and adults with dyslexia, Bouldoukian, Wilkins and Evans, (2002) showed significant improvement with the cover overlay in comparison to a control overlay. More recent research, Singleton and Henderson (2007), identified 9 children from a sample of 22 dyslexic children who showed mild evidence of visual stress, whose reading speed and symptoms were improved by the use of coloured overlays. However, Barrett (2009), cautions that there is a paucity of controlled trials of behavioural optometry, and the large majority of approaches are not evidence based. The evidence suggests that scotopic sensitivity is a recognised problem which can be ameliorated by the use of the appropriate coloured lens, but that it is found in the general population as well as in dyslexia.

X.iv Pharmaceutical/Dietary Approaches

There is increasing interest in the roles of fatty acids metabolism in neurodevelopmental disorders such as dyslexia, ADHD, dyspraxia and autism (Richardson & Puri, 2000; Richardson & Ross, 2000 & Richardson 2001). Fatty acids are chains of carbon atoms linked together by chemical bonds. They provide energy for the muscles, heart, other organs, building blocks for cell membranes and an energy store for the body (http://www.medicinenet.com/script/main/art.asp?articlekey=23820). Specific highly unsaturated fatty acids are thought to be essential for the normal structure of neuronal membranes, cell signalling and regulatory roles in a range of physiological functions (Richardson & Puri , 2000). Inefficiency/deficiency in the conversion of essential fatty acids to highly unsaturated fatty acids has been proposed as a factor in dyslexia as well as other neurodevelopmental disorders (Richardson & Ross, 2000).

Fatty acids research

The most recent evidence emerging on fatty acids and dyslexia in adults by Richardson and her colleagues (Cyhlarova et al., 2007) showed that reading performance in both dyslexics and controls was linked to higher total Omega-3 concentration, and that for dyslexic participants it was negatively related to Omega-6 concentration, suggesting that it is the balance between the two which is relevant to dyslexia. However, more recent double blind placebo controlled studies, (Kairaluoma et al, 2009) have shown no effects of supplementation with unsaturated fatty acids on reading accuracy or speed, spelling, decoding, arithmetic, language skills attention or

behaviour. Kirby, Woodward, Jackson, Wang and Crawford (2010) showed in a double blind placebo controlled study in typically developing children aged 8-9 years in Wales, that there was no improvement in reading and spelling skills when being given a fatty acid supplement but there was improvement in attention skills noticed by teachers. Current research evidence of the relationship between fatty acids and dyslexia are mixed and further research is needed in order to clarify the nature of this relationship.

X.v Approaches using New Technology

Fast ForWord

This is a computer-based instructional programme designed to improve a deficit in processing rapidly changing sensory inputs by modifications to the acoustic and temporal properties of speech signal (Tallal et al., 1996; Gillarn et al., 2008). Its development was based on the hypothesis that temporal deficits were one of the causes of the phonological and language difficulties experienced by children with language learning impairments (Tallal et al., 1996). The programme includes a series of seven computer-based exercises with acoustically modified non-speech and speech stimuli (Fey et al, 2010).

This intervention approach and the science behind it have received considerable research attention in the fields of language impairment and dyslexia, as discussed in Chapter III (e.g., Marshall, Snowling, & Bailey, 2001; McArthur & Bishop, 2001; Merzenich, et al., 1996; Mody et al., 1997), and on balance, the findings show that a deficit in processing rapid acoustic changes is not a defining feature of dyslexia, however, subsamples of dyslexic children who also have concomitant oral language difficulties tend to show poor performance on Tallal's auditory processing tests (Tallal & Stark, 1982; Heath, Hogben, & Clark, 1999). In addition, the evidence shows that the deficit in rapid auditory processing is not a likely causal correlate of reading problems (see also Chapter III).

In a controlled study Hook et al. (2001) found that their Fast ForWord group showed significant gains in phonemic awareness following intensive training, but these were time-limited. At a 2-year follow-up, gains in spoken language and reading were no greater than those of a control group that received no intervention; moreover, they were less advanced than children undertaking a more traditional intervention.

Most recent evaluations of the suite of Fast ForWord products, drawn from the IeS US Department of Education website (July, 2007) have identified five studies from the 115 which they reviewed which meet their stringent criteria for evidence standards, based on randomized controlled trials. More than half of the studies reviewed were reports from *Scientific Learning Corporation*, who distribute Fast ForWord. These studies, including 587 children from kindergarten to 3rd grade show that there were positive effects on alphabetic, and mixed effects on comprehension, but the website considers the evidence for improvement to be small. None of the studies meeting the criteria address effects on fluency or general reading achievement.

More recent independent studies (Borman, Benson, & Overman, 2009) with a randomised field trial in 8 schools found that the Fast ForWord language programme had some problems in implementation in the field and did not generally impact on language and reading comprehension test scores. Furthermore, studies (Given et al., 2008; Gillarn et al., 2008) have compared Fast ForWord, and Fast ForWord-plus-language exercises, and found no differential effect of Fast ForWord on progress. Consistent with other findings that some children with oral language difficulties do show impairments in rapid auditory processing, individual case studies have reported evidence of normalisation of auditory processing and improvements in comprehension and spelling (Lajiness-O'Neill, Akamine, & Bowyer,
2007), and improvements in language and selective attention (Stevens et al, 2008).

Conclusions on Fast ForWord

The effectiveness of Fast ForWord remains controversial, although Merzenich and colleagues (e.g., Temple et al., 2000) are now showing evidence of changes in the brain following completion of training which suggest a normalisation of the processing underlying reading. Fast ForWord is used widely in the USA, with over 570,000 students using the programme in 3700 schools nationwide. Schools taking part buy a licence for use of the programme, with costs ranging from $500–$900 depending on the programme. The most recent randomised

trials indicate that Fast ForWord is not differentially effective at improving skills, although it may be indicated for specific children with problems in speeded processing of auditory stimuli.

X.vi Measuring Progress: The Techniques

In order to evaluate change, a range of parameters need to be measured, which include the effectiveness and cost effectiveness of the change; that is: how strong is the effect of the therapy, and how much money does it cost to achieve it? Other important questions concern whether the change is general rather than specific, and is the training a primary (directly causal) or a secondary indirect effect. Moreover, are the changes due to Placebo, Hawthorne, or Pygmalion effects? A placebo effect is based on the expectation of change, so that even a sugar pill will produce the effects which have been described. A Hawthorne effect is based on the extra interest taken in the children, which leads them to blossom under the positive input. Finally, the Pygmalion effect is found when teachers are simply told to expect great things from certain children, and their re-evaluation of the potential of the children indeed leads to improvements. The causes of the change are therefore critical in evaluating therapies
– have they led to changes in the brain, to changes in cognitive behaviour, or is it simply the environment which has changed thus allowing a child the possibility of greater success. Finally, how valuable is the change, will it transfer to other skills, lead to permanent improvements, and what efforts will be needed to maintain progress?

X.vii The Limitations of Alternative Approaches

It may be seen from the questions above that it can be difficult to evaluate therapies objectively, and that how useful they seem may be critically dependent on who is evaluating them, theorist, policy maker, practitioner, or product distributor. It is important to recognize that there different parameters for success and failure. Parents and their children seek immediate effects, and may not really be concerned as to why an intervention works, only whether it does. Indeed, for most parents, happiness is a more salient criterion than literacy. It seems that most one-to-one interventions will be fairly effective, even if only via general factors. Some alternative therapies appeal to the desire to focus on the whole child, rather than on their (under)achievements. Improving the child's self-esteem, health with dietary supplements, auditory processing, or cutting down the aversive glare which affects their ability to concentrate, can all have potent effects on wellbeing and even on school progress. However, convincing evidence of improvements in literacy attainments through causal distal effects on cerebral structures, for example, is still wanting. While well-attested phonology-orthography-based interventions work very effectively for most children, it is a fact that those with the most severe forms of developmental dyslexia do not respond even to interventions meeting the standards of best practice (e.g., Torgeson et al., 2006; Whitely et al., 2007). Moreover, accruing evidence suggests that the most severe cases of developmental dyslexia occur in children who have concomitant overlapping disorders. This suggests that the search for effective remedial approaches will need to be multifaceted, and potentially will require a complex combination of interdependent therapies. This state of affairs calls all the more emphatically for further well-designed and well evaluated research, which will generate interventions that can be shown to have *direct causal* effects in remediating children's literacy and associated difficulties.

Conclusion

In this review we have considered a range of alternative therapies, and why they may be gaining ground. We have considered the strengths and weaknesses of these approaches, and cautioned against uncritically accepting claims based on anecdotal evidence and published on websites. We have discussed the issues arising around methodologies for evaluating interventions, and discovered that the majority of studies on which we base our thinking do not satisfy the most stringent criteria. We have discussed the differences in outlook between researchers, practitioners and parents, and how these differences may affect the type of support sought. We have advocated a system of benchmarking which can identify whether there is any evidence for the usefulness of alternative therapies, and which type of child might benefit, in order to provide information to parents. It is important to bear in mind that children show different profiles of difficulty, within the syndrome of dyslexia, dyslexia plus ADHD and dyspraxia. Research indicates that early interventions are the most effective in

'accelerating' literacy for many children, but those children who are resistant to intervention will show entrenched problems and need intensive 1:1 support such as provided by standard reading therapy. A combination of traditional teaching and alternative therapy might well prove the most effective, producing truly multi-sensory teaching for some children with severe and complex difficulties. However, overall, if a choice must be made between alternative and traditional approaches, we would only ever see alternative therapy as complementary to the tried and tested traditional interventions with which we are all familiar. In addition there is now a growing body of opinion, significantly from the adult area (McLaughlin & Leather, 2008), to suggest that we should be focusing on support rather than remediation and enhancing the understanding of those in contact with people with dyslexia (teachers and employers) in addition to identifying more effective learning methods.

XI. LOOKING TO THE FUTURE

In this closing section, some of the key implications that arise from this literature review about understanding and remediating dyslexic difficulties are highlighted. They are presented separately for research and for practice, although it is our hope that these two spheres of activity will remain closely interdependent.

XI. I Implications for Future Research

The present literature review reported on the great advances that have been made in understanding, identifying and remediating the difficulties of children with dyslexia. Nevertheless, many questions still remain unanswered, and some issues continue to pose a challenge, not least the need to uncover how best to intervene with those severely dyslexic children who remain unresponsive even to the best and most effective intervention programmes. In order to make further advancements, systematic high quality research is needed that will include 'marker tasks' indexing the deficits proposed by different theories, for direct comparison. This approach will enable researchers to evaluate different theories and to establish how far they interlink. An important objective of future research should be to aid in early identification of risk factors not only of dyslexia, but also of those conditions that are known to co-occur with and to compound the severity of dyslexic difficulties, such as SLI. Excellent existing examples of research programmes taking this approach include: Bishop, McDonald, Bird, & Hayiou-Thomas, 2009; Ramus, Pidgeon and Frith, 2003; Heath, Bishop, Hogben, & Roach, 2006.

Areas for further research

Among the most important are questions touching on issues such as multidimensional profiles, comorbidity, pre-school development, and the expression of dyslexia in different languages and in bilinguals (e.g., Welsh-English).

Multidimensional Profiles (or Subtypes). Do some dyslexic children show multiple deficits, and others show only a speed or a phonological deficit, or do most children show a profile with elements of all the deficits, but with some deficits more striking than others? Moreover, are all of a child's presenting deficits related to his/her literacy difficulties? This complex issue awaits much further research.

Comorbidity or co-occurrence. There is clear evidence of overlap between different developmental disorders, with large percentages of children (30% or more) showing language impairments, developmental coordination disorder, attention deficit hyperactivity disorder or conduct disorder, in addition to dyslexia (Bishop & Snowling, 2004). Understanding the causes and developmental profiles of children with different comorbid conditions still requires much investigation.

Early development. Infancy and early childhood studies involve in-depth longitudinal studies; they are particularly important, because they have the potential to identify 'marker tasks' of dyslexia in the youngest groups of all, and to advance research on early identification and prevention of problems.

Cross-linguistic studies. This research area is especially important for Welsh context. The expression of dyslexic profiles is mediated by the child's native spoken and written language. Remarkably little has been documented about the manifestation of dyslexia in speakers/readers of Welsh. Moreover, there is growing interest in the impact of bilingualism and multilingualism on dyslexics' difficulties and development; is it a hindrance or a benefit to learn in two languages if one is dyslexic? The bilingual (and often multilingual) context of Wales provides an excellent opportunity for investigations into these questions. Wales could be at the forefront of this currently under-explored research field.

XI.ii Implications for Provision in Wales

Provision

Dyslexia has traditionally been regarded as a specific learning disability, and as such it has remained almost exclusively (apart from some involvement from Speech and Language Therapists) within the field of education for purposes of assessment, diagnosis and remediation approaches. This is in contrast to other developmental

disorders such as Dyspraxia/DCD and ADHD which are also referred to as specific learning disabilities, but which sit within the purview of Health professions, still others such as ASD straddle both agencies. The rationale for these divisions is not clear.

Comorbidity and Co-occurrence

This literature review has reviewed definitions of dyslexia issued by eleven national and international bodies, including the World Health Organisation. Within these definitions, Literacy Skills is the only universally recognised component of dyslexia, with nine of the eleven organisations also citing phonological deficits. Other components of dyslexia identified within these definitions indicate that it is increasingly seen as a complex multi-factorial disorder containing elements that also occur in other Specific learning disabilities. Seven of the eleven definitions reviewed in this study record the presence of motor/movement difficulties and (dyspraxia/DCD) within the dyslexic population, and six also refer to the presence or co-occurrence of attention difficulties (ADD and ADHD).

In common with other specific learning difficulties 'pure' cases of Dyslexia are, therefore, increasingly seen as the exception rather than the rule. Awareness of the multiple factors that contribute to, and compound the child's difficulties presents a challenge for professionals across agencies to develop ways of working to together, and to view the child holistically in order to identify all of the child's difficulties in order to improve his/her ability to learn.

Provision for children with dyslexia and other specific learning disabilities is variable across authorities in Wales. There is very little consistency to be found in regard to type and delivery of services. There is a range of screening and assessment tools in use, different definitions are used, and a variety of intervention approaches are applied. Variance in provision is also seen in other specific learning disabilities such as Dyspraxia/DCD, ADHD and ASD.

Multi-disciplinary Working

Children with overlapping learning disabilities may need support from several professional groups across agencies. This was recognised by the Special Educational Needs Code of Practice and the National Service Framework for Children (2006) which advocate multi-disciplinary, joint agency working to provide seamless services to children and families. To date there has been little progress towards multidisciplinary working within these professional groups, exceptions to this include the Swansea LA where real efforts have been made to develop 3 multi-disciplinary pathways for children with ADHD, dyspraxia or ASD (Salmon, Cleave, & Samuel, 2006). A multidisciplinary pathway has also been under development in North East Wales across Wrexham and Flintshire.

The SEN Code of Practice also provides a framework for dealing with escalating concerns and providing support for children demonstrating learning difficulties. The model contained within the Code of Practice requires class teachers to monitor the child's progress in literacy and numeracy and to provide additional support where needed. Advice and support can be sought from ANCOs at this level. If the child shows little or no progress following the additional support the concerns can be escalated in this graduated approach to School Action and School Action Plus. It is only in the latter stage that advice and support would be sought from external professionals. As the model of service delivery described in the Code of Practice is silent in regard to timeframes for escalation through the stages, this potentially precludes valuable specialists' information from being provided for the school at a stage in early schooling before the child's difficulties become entrenched.

Holistic Assessment

The current review fully endorses the requirement for early identification and early intervention for children with dyslexia and other specific learning disabilities. Moreover, an arising implication for best practice is that a child's suspected additional difficulties also be considered for early identification, as diagnosing comorbid or co-occurring difficulties may improve the 'high-risk child's' prospects of timely and effective remediation.

The requirement for enhanced specialist assessment in the earlier stages need not place greatly increased demand on individual specialist services. It is recognised that class teachers would be best placed to assess and monitor the development of the simple but critical letter knowledge and phoneme awareness skills. Although

they would not have sufficient time to carry out more detailed assessments which are the responsibility of specialist, they could also undertake screening and monitoring of more areas of concern given additional training. This could be included in the curriculum for teacher training. By supporting teachers to undertake wider screening of potential areas of difficulty for children they should also be more empowered to seek the additional advice or assessment that they feel is required.

Intervention

With regard to intervention for children with dyslexia, this review has identified that the timing of the phonics-based literacy intervention is most critical. The benefit of early intervention for children with dyslexia and all other specific learning difficulties cannot be over-emphasised. The completion of holistic assessments in the early years need not lead to multiple specialist assessments at that time if more broad based developmental programmes are introduced to schools (and some such programmes incorporating the building blocks for more complex activities, including language, auditory and visual perception, body awareness, spatial awareness, balance, co-ordination, etc., have already been successfully introduced into some schools in Wales and Scotland). The objective should be to provide integrated, high quality, holistic support based on the needs of the child (SEN Code of Practice).

XI.iii Toward a Definition of Dyslexia

As indicated in Chapter II and throughout this Literature Review, the definition of dyslexia has evolved from a conceptualization of a reading deficit that can be identified with respect to the *discrepancy* between one's expected attainment, based on IQ, and his/her 'unexpectedly' low observed attainment. Broader intellectual ability is now seen as less critical to the identification of dyslexia; a child may be dyslexic regardless of his/her IQ. Another development in the field has centred on the recognition that many children with dyslexia also present with other developmental disorders. That is, dyslexia frequently occurs with one or more other developmental problems, and the nature of the interactions between multiple disorders is now the subject of intense research. Investigations into this issue are focusing on the biological bases, the neurocognitive processes, and behavioural markers of complex dyslexic difficulties. These developments have clear implications for support and intervention in teaching practice, as elaborated above. Importantly, however, the above developments have NOT led most researchers to conclude that dyslexia does not exist, nor that it is a general problem that includes any number of other developmental disorders. The research, in large majority, clearly confirms that dyslexia manifests as a specific learning difficulty affecting reading and spelling ability, with difficulties in phonological processing at its core. As pointed out by the Rose Review (2009), other frequently co-occurring difficulties may compound dyslexic difficulties but are not, by themselves, markers of dyslexia.

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APPENDIX A

List of Tables

Table A1

Detailed summary of definitional components of dyslexia by 11 national and international organizations and bodies.

Organizations	IQ Discrepancy	Phonological Deficit	Pervasive/Lifelong	Literacy Difficulties	Short Term/Working Memory Deficit or Verbal Memory Deficit	Processing Speed Deficit	Hereditary	Co-morbid with other Developmental Disorders	Attention Deficit Hyperactive Disorder	Cross Cultural	Severity Continuum mild to severe	Sensory Processing	Resistant to Conventional Teaching Methods	Effects of Disorder Mitigated by Targeted Intervention
British Dyslexia Association	✓	✓	✓	✓	✓	✓	Silent	Silent	Silent	Silent	Silent	Silent	✓	✓
British Psychological Society	Silent	Silent	Silent	✓	Silent	Silent	Silent	Silent	Silent	Silent	Silent	Silent	✓	Silent
Dyslexia Action	×	✓	✓	✓	✓	Silent	Silent	✓	Silent	✓	✓	✓	Silent	✓
Department of Education and Skills	×	✓	Silent	✓	✓	✓	✓	✓	Silent	Silent	✓	Silent	Silent	Silent
Rose Review	×	✓	Silent	✓	✓	✓	✓	Silent	Silent	Silent	✓	Silent	Silent	✓
Dyslexia Scotland	✓	✓	✓	✓	✓	Silent	✓	Silent	✓	✓	✓	Silent	✓	Silent
Learning and Teaching Scotland	✓	✓	✓	✓	✓	Silent	✓	Silent	Silent	✓	✓	Silent	✓	✓
ICD- 10	✓	✓	Silent	✓	Silent	Silent	Silent	✓	Silent	✓	✓	Silent	Silent	Silent
DSM- IV-TR	✓	Silent	Silent	✓	Silent	✓	Silent	✓	Silent	Silent	Silent	Silent	Silent	Silent
International Dyslexia Association	✓	✓	Silent	✓	Silent	Silent	Silent	Silent	Silent	Silent	Silent	Silent	✓	Silent
National Institutes of Health (US)	✓	✓	Silent	✓	Silent	✓	Silent	Silent	Silent	Silent	Silent	Silent	Silent	Silent
Total	7	9	4	11	6	5	4	4	1	4	6	1	5	4

Note. 1. IQ Discrepancy: a disparity between an individual's literacy skills and what is expected based on their IQ score (BPS, 1999). 2. Phonological Deficit: any difficulty experienced in processing sounds in the spoken language, including phoneme segmentation, spoonerisms and non-words. 3. Literacy Difficulties: difficulties acquiring literacy skills reading, spelling or writing. 4. Short Term/Working Memory Deficits: difficulty retaining information necessary for performing tasks. 4a. Verbal Memory Deficits: difficulty retaining the spoken word. 5. Processing Speed Deficits: slow rate and inefficiency with which information is processed.

Table A2
Brief Descriptions of Primary Screening and Assessment Tests – Based on Lists Compiled by the BDA.

Age Group	Test	Description	Publisher
3y6m-4y5m	Pre-school Screening Test (PREST) (s)	Pre school screening of attainment.	Pearson Assessment
5-8	Lucid CoPS (A)	Computer assessment and profiling system for all SpLDs.	Lucid Research
4y6m-6y5m	DEST 2 (S)	Battery of tests of ability and attainment for dyslexic difficulties.	Pearson Assessment
4-15	Lucid Rapid (s)	Fast accurate computer screener Prints out results.	Lucid Research
5-14	Special Needs Assessment Profile (Snap) (s)	For all SpLds. Computer profiling	Hoddertests
8-11	Lucid Assessment System for School (LASS Junior) (A)	Computer assessment and profiling system for all SpLDs.	Lucid Research
6y6m-16y6m	Bangor Dyslexia Test (BDT) (s)	Battery of tests.	Bangor Dyslexia Unit
6-14	Dyscalculia Screener (s)	Computer screening test	GL Assessment
5-16	Dyslexia Screener (s)	Computer screening test	GL Assessment
7-11	Lucid VISS primary	Computer screener for visual stress in reading (Mearles-Irlen Syndrome).	Lucid Research
9-12	Detailed Assessment of Speed of Handwriting (DASH)	Assess handwriting speed	Pearson Assessment

Note. S – Screening Test. A – Requires specialist knowledge. Adapted from the British Dyslexia Association.

Table A3
Brief Description of Secondary Screening and Assessment Tests – Based on Lists Compiled by the BDA.

Age Group	Test	Description	Publisher
5-14	Lucid Rapid (s)	Fast accurate computer screener Prints out results.	Lucid Research
5-14	Special Needs Assessment Profile (Snap) (s)	For all SpLds. Computer profiling.	Hoddertests
6-11y5m	DST Secondary (S)	Battery of tests of ability and attainment for dyslexic difficulties	Pearson Assessment
11-15	Lucid Assessment System for School (LASS Secondary) (A)	Computer assessment and profiling system for all SpLDs.	Lucid Research
6y6m-16y6m	Bangor Dyslexia Test (BDT) (s)	Battery of tests.	Bangor Dyslexia Unit
6-14	Dyscalculia Screener (s)	Computer screening test.	GL Assessment
5-16	Dyslexia Screener (s)	Computer screening test.	GL Assessment
11-17	Lucid VISS Secondary	Computer screener for visual stress in reading (Mearles-Irlen Syndrome).	Lucid Research

Note. S – Screening Test. A – Requires specialist knowledge. Adapted from the British Dyslexia Association.

Table A4

Brief Description of Individual Attainment and Ability Tests – Based on Lists Compiled by the BDA.

Age Group	Test	Description	Publisher
6-25	Test of Word Reading Efficiency (TOWRE)	Reading.	Pearson Assessment
6-19	Gray Oral Reading Test Fourth Edition (GORT-4)	Oral Reading.	Pearson Assessment
6-19 (7-25)	Gray Silent Reading Test (GSRT)	Silent Reading.	Pearson Assessment
16 – 55	Adult Reading Test (ART)	Oral Reading	Pearson Assessment
16+	Advanced Reading Comprehension (ARC)	Silent Reading	University of Hull
6-13	Neale Analysis of Reading Ability (NARA)	Reading.	GL Assessment
5-adult	Wide Range Achievement Test 4 (WRAT4)	Reading, spelling, maths.	Pearson Assessment
3-6	Preschool and Primary Inventory of Phonological Awareness (PIPA)	Phonological.	Pearson Assessment
5-7	Phonological Ability Test (PAT)	Phonological.	Pearson Assessment
5- 25 years	Comprehensive Test of Phonological Processing (CTOPP)	Phonological processing.	Pearson Assessment
7+	Wordchains	Phonological.	GL Assessment
6-14y11m	Phonological Assessment Battery (PhAB)	Phonological assessment battery.	GL Assessment
5-18	Vernon	Spelling.	Hodder Education
4- 85 years	Wide Range Intelligence Test (WRIT)	Cognitive ability.	Pearson Assessment
4-8, 7-12, 11-16	Lucid Ability	Computerised assessment of verbal and non-verbal reasoning.	Lucid Research
5-75 + years	Woodcock Reading Mastery Tests (WRMT-R)	Word Identification	Pearson Assessment
4- 86 years	Wechsler Individual Achievement Test – 2nd UK Ed. (WIAT-II UK)	Word Reading	Pearson Assessment
6- 89 years	Wechsler Abbreviated Scale of Intelligence (WASI)	Cognitive Ability	Pearson Assessment
7- 19 years	WRAT- Expanded Group Assessment (Form G) Mathematics Test	Attainment in numeracy	Harcourt Assessment
7 – 25 years	WRAT-Expanded Individual Assessment (Form I) Mathematics Test	Attainment in numeracy	Harcourt Assessment

Note. Adapted from the British Dyslexia Association.

Table A5
Brief Description of Adults Screening and Assessment Tests – Based on Lists Compiled by the BDA.

Test	Description	Publisher
SPOT (s)	Screening and profiling online test.	BDA website
Lucid Adult Dyslexia Screening (LADS) (s)	Computer screening test for use in universities/colleges.	Lucid Research
Lucid Adult Dyslexia Screening Plus Version (LADS Plus) (s)	As above for a general population.	Lucid Research
Quickscan (s)	Computer screening test for use in universities/colleges.	Pico
Lucid VISS Adult	Computer screener for visual stress in reading (Mearles-Irlen Syndrome).	Lucid Research
Wechsler Adult Intelligence Scale 3rd Ed. UK Version (WAIS-III UK)	Cognitive Ability	Pearson Assessment
Wechsler Memory Scale 3rd Ed. UK Version (WMS- III)	Working Memory	Pearson Assessment

Note. S- screening test, A - Requires specialist knowledge. Adapted from the British Dyslexia Association.

Table A6

List of Suitable Tests for the Diagnosis and Assessment of Dyslexia in Children and Adults.

ATTAINMENTS IN LITERACY						
Name of Test	Closed/ Open	Age Range	Admin. Time	Publisher and Distributors	Components	Comments
Reading: Single Word Recognition						
Wide Range Achievement Test 3 (WRAT3)	Open	5-75 years	5-10 mins	Psychological Assessment Resources, Inc., USA/Harcourt Assessment/Dyslexia Institute.		Co-normed with WRIT.
Woodcock Reading Mastery Tests (WRMT-R)	Open	5-75+ years	Approx 10 mins	American Guidance Service, USA/Dyslexia Institute.	Word Identification	
Test of Word Reading Efficiency (TOWRE)	Open	6-24.11 years	5 mins	Pro-Ed, USA/Taskmaster/Dyslexia Institute/Harcourt Assessment.	Sight Word Efficiency subtest with alternate forms.	Timed test measuring fluency reading real words. Together with the TOWRE (nonword) Phonemic Decoding Efficiency test, yields a Reading Efficiency measure. Can be used for ages over 24.11 years.
Reading: Continuous Text Reading – Oral Reading						
Spadafore Diagnostic Reading Test (SDRT)	Open	6-Adult	Varies	Academic Therapy Publications, USA/Ann Arbor		An appropriate passage can be used for miscue analysis purposes.
The Adult Reading Test (ART)	Open	16-55 years	30 mins	Harcourt Assessment	Reading accuracy; reading comprehension; speed of reading, speed of writing	Reading aloud; comprehension questions are factual and inferential. In the case of dyslexia advised to obtain a sample of free writing from a period over 2 minutes.
Gray Oral Reading Test Fourth Edition (GORT-4)	Open	6-18.11 years	15-45 mins	Pro-Ed, USA/Harcourt Assessment.	2 parallel forms; 14 paragraphs; 5 comprehension questions per paragraph.	Rate; Accuracy; Fluency; Comprehension; Oral Reading Quotient. Student can not refer back to the passage for answers to comprehension questions. Can be used qualitatively for ages over 18.11 years.

Name of Test	Closed/ Open	Age Range	Admin. Time	Publisher and Distributors	Components	Comments
Reading: Silent Reading						
Gray Silent Reading Test (GSRT)	Open	7-25 years	10-15 mins	Pro-Ed, USA/Harcourt Assessment.	2 parallel forms; 13 paragraphs; 5 comprehension questions per paragraph;	Different types of comprehension questions. Group administration is possible. Multiple-choice format.
Spadafore Diagnostic Reading Test (SDRT)	Open	6-Adult	Varies up to 30 mins	Academic Therapy Publications, USA.		An appropriate passage can be used. Literal recall and inference comprehension questions. Student can not refer back to the passage for answers to comprehension questions. Comment on reading speed.
Advanced Reading Comprehension Test (ARC)	Open	Adult	20 mins	Department of Psychology, University of Hull.	Two Versions (M & C)	Normed under timed conditions; standardization sample may be slightly above the average for the UK HE sector as a whole. Further standardisation using students from a wider range of HE Institutions is expected.
WRAT-Expanded Group Assessment (Form G) Reading Comprehension Test	Open	7-18.11 years	50 mins	Psychological Assessment Resources, Inc., USA/Harcourt Assessment/Dyslexia Institute.		Multiple-choice; can be used individually. Can be used qualitatively for ages over 18.11 years.
WRAT-Expanded Individual Assessment (Form I) Reading Comprehension Test	Open	7-24.11 years	Approx 15 mins	Psychological Assessment Resources, Inc., USA/Harcourt Assessment/Dyslexia Institute.		Multiple-choice; can be used individually. Can be used qualitatively for ages over 24.11 years.
Woodcock Reading Mastery Tests (WRMT-R)	Open	5-75+ years	Approx 15 mins	American Guidance Service, USA/Dyslexia Institute.	Passage Comprehension	Modified cloze procedure

Name of Test	Closed/ Open	Age Range	Admin. Time	Publisher and Distributors	Components	Comments
Reading: Single Nonword Decoding						
Test of Word Reading Efficiency (TOWRE)	Open	6-24.11 years	5 mins	Pro-Ed, USA/Taskmaster/Dyslexia Institute/Harcourt Assessment.	Phonemic Decoding Efficiency subtest with alternate forms.	A timed test measuring fluency of reading nonwords. Together with the TOWRE Sight Word Efficiency test gives overall Reading Efficiency score. Qualitative use for ages over 24.11 years.
Woodcock Reading Mastery Tests (WRMT-R)	Open	5-75+ years	Approx 10 mins	American Guidance Service, USA/Dyslexia Institute	Word Attack	An untimed, graded nonword reading test.
Non-word Decoding Test	Open	Non-standardised use	5-10 mins	Dyslexia Institute		
Wide Range Achievement Test 3 (WRAT3)	Open	5-75 years	5-10 mins	Psychological Assessment Resources, Inc., USA/Harcourt Assessment /Dyslexia Institute		Co-normed with WRIT.
Spelling & Writing						
Helen Arkell Spelling Test (HAST)	Open	5-19+ years	Approx 15-20 mins	Helen Arkell Dyslexia Centre	Includes high and low frequency, and regular and irregular words.	Standardised on UK population. Can be used for group or one-to-one testing.
British Spelling Test Series (BSTS)	Open	15.6-24+ years	30 mins	NFER-Nelson	Series 5 (X/Y forms)	Can give information about dictation abilities and proof reading abilities.
Free Writing	Open	Non-standardised	Up to 15 mins	Note: Timed – up to 15 minutes. Writing speed score can be obtained; comparison of spelling usage and single word spelling. Comment on: structure, punctuation, spelling in context, organisation, legibility & use of vocabulary. Student can either: (1) choose a topic to write about, (2) write about a topic in his/her area of study or (3) write about a passage he/she has read, putting in the key points. (1) & (2) can be used for the Speed of Writing Prose Task.		

UNDERLYING ABILITY						
Name of Test	Closed/ Open	Age Range	Admin. Time	Publisher and Distributors	Components	Comments
Listening Comprehension						
Wide Range Intelligence Test (WRIT)	Open	4-85 years	20-30 mins	Psychological Assessment Resources, Inc., USA/Dyslexia Institute	Verbal (Vocabulary & Verbal Analogies); Visual (Matrices & Diamonds).	High correlation with WAIS-III & WISC-III; co-normed with WRAT3. Published 20 00.
Wechsler Adult Intelligence Scale, 3rd Edition UK version (WAIS–IIIUK)	Closed	16-89 years	75 mins	Harcourt Assessment.	Indices: Verbal Comprehension; Perceptual Organisation; Working Memory; Processing Speed.	Published 1999 (superseded WAIS–R).
Wechsler Abbreviated Scale of Intelligence (WASI)	Closed	6-89 years	30 mins	Harcourt Assessment	Verbal Scale; Performance Scale.	Published 1999.

COGNITIVE PROCESSING						
Name of Test	Closed/ Open	Age Range	Admin. Time	Publisher and Distributors	Components	Comments
Listening Comprehension						
Spadafore Diagnostic Reading Test (SDRT)	Open	6 – Adult	Varies	Academic Therapy Publications, USA		An appropriate passage can be used.
Working Memory						
Wechsler Memory Scale, 3rd Edition UK (WMS–III)	Closed	16-89 years	75 mins	Harcourt Assessment.	Immediate Memory; General Memory; Logical memory; Working Memory (span).	Published 1999.
Wide Range Assessment of Memory and Learning Second Edition(WRAML2)	Open	5-90 years	20+ mins	Psychological Assessment Resources, Inc., USA/ Harcourt Assessment	6 core tests; 2 optional delay recall tests; 4 optional recognition tests; 3 optional memory tests	The factor structure contains verbal memory, visual memory and attention/concentration information. Excellent range of memory tests.
Name of Test	Closed/ Open	Age Range	Admin. Time	Publisher and Distributors	Components	Comments

Wechsler Adult Intelligence Scale, 3rd Edition UK (WAIS–IIIUK)	Closed	16-89 years	10-15 mins	Harcourt Assessment.	Digit Span; Letter-Number Sequencing.	
The Digit Memory Test	Open	6-Adult	5-10 mins	Dyslexia Institute	Digit Span forward and backward	
Phonological Processing						
Comprehensive Test of Phonological Processing (CTOPP)	Open	5-24.11 years	30 mins	Pro-Ed, USA/Taskmaster	Quotients: Phonological Awareness; Phonological Memory; Rapid Naming.	Can be used qualitatively for ages over 24.11 years.
Speed of Processing						
Symbol Digit Modalities Test (SDMT)	Open	8-Adult	90 secs	WPS, USA/Dyslexia Institute	Matching number with symbol.	Similar to Digit-Symbol Coding sub-test of WAIS III; administered as written and/or oral test; measure of speed of processing.
Comprehensive Test of Phonological Processing (CTOPP)	Open	5-24.11 years	30 mins	Pro-Ed, USA/Taskmaster	All Rapid Naming subtests & Quotients.	
Wechsler Adult Intelligence Scale, 3rd Edition UK (WAIS–IIIUK)	Closed	16-89 years	10 mins	Harcourt Assessment.	Processing speed index.	
Speed of Writing Prose Task	Open	Adult	Up to 15 mins			Timed - up to 15 mins. Student can choose topic to write about. Provides words per minutes and indicates speed of processing. Can also be used for the Free-Writing Task.
ATTAINMENTS IN NUMERACY						
Wide Range Achievement Test 3 (WRAT3)	Open	5-75 years	15 mins	Psychological Assessment Resources, Inc., USA/ Harcourt Assessment/Dyslexia Institute		Timed test; quick to administer; only tests arithmetic skills; presentation of items is in an American format

Name of Test	Closed/ Open	Age Range	Admin. Time	Publisher and Distributors	Components	Comments
WRAT-Expanded Group Assessment (Form G) Mathematics Test	Open	7-18.11 years	45 mins	Wide Range Inc, USA/ Harcourt Assessment/Dyslexia Institute		Can be used individually; multiple-choice; assesses understanding of concepts, computation and problem solving. Used qualitatively for ages over 18.11 years.
WRAT-Expanded Individual Assessment (Form I) Mathematics Test	Open	7-24.11 years	Approx 15 mins	Psychological Assessment Resources, Inc., USA/ Harcourt Assessment/Dyslexia Institute		Multiple-choice; assesses understanding of concepts, computation and problem solving. Can be used qualitatively for ages over 24.11 years.
Mathematics Competency Test	Open	11.6 - Adult	30-40 mins	Hodder & Stoughton	Using & Applying Mathematics; Number & Algebra; Space & Shape; Handling Data	Useful for students who have difficulty with mathematics; gives percentile scores only; can be used qualitatively.
ATTAINMENTS IN MOTOR CONTROL						
Morrisby Manual Dexterity Test	Open	14-49 years	5 mins	The Morrisby Organisation		Fine motor control indicators for dyspraxic-type difficulties

Note. Adapted from The Professional Association of Teachers of Students with Specific Learning Difficulties (PATOSS) http://www.texticweb.com/patoss/downloads/STECDfESGuidelines20092010.pdf

Interventions

The literature reviews

(It should be noted that although these reviews are comprehensive and well received, none are peer reviewed or published in journal form.)

i) Slavin (2009). These reviews taken from the website Best Evidence Encyclopedia examine the impact of different reading approaches with beginning and struggling readers, and include interventions of 12 weeks or longer, which represent strong, medium, or weak evidence, with effect sizes of at least 0.20. The method is known as best evidence synthesis, and uses well-justified standards to evaluate studies and to pool effects. Slavin included 96 quasi experimental-control comparisons, 39 of which were randomized and five quasi experimental.

ii) Singleton (2009) notes that there is a dearth of well-controlled studies with children with known difficulties, and acknowledges the need to recognize 'silver standard' studies using quasi- experimental designs including pre and post tests, some of which may not include controls. Singleton therefore includes some research that has not been published in peer reviewed journals, or has been presented at conferences.

iii) Brooks (2007) has similarly included unpublished material, more specifically studies that have investigated intervention approaches that he finds promising.

iv) What Works Clearinghouse 2007 http://ies.ed.gov/ncee/wwc/reports. This website maintained by the US department of education includes sections on beginning reading (ages 5-8) and adolescent reading, as well as achievement more generally. This website allows searches for specified interventions, and includes single case studies as well as randomized trials and quasi experimental studies.

v) Fawcett (2002). This review for the DfES website included an analysis of current publications plus the findings of the US National Reading Panel.

It is particularly interesting to cross reference across these reviews and to identify strong UK intervention studies which have been highlighted in a range of US and UK reviews. We summarize these works in the Table of reviews and Meta-analyses in Tables A7 & A8.

Table A7

Summary of Intervention Studies in Decreasing Order of Effect Size.

Studies	**Intervention Study/Programme**	**Year Group**	**Sample Size**	**Taught by**	**Effect Size**		**Source**
					Reading Accuracy	**Spelling Accuracy**	
Primary Level							
Solity, J. E., Deavers, R., Kerfoot, S., Crane, G. and Cannon, K. (2000)	The Early Reading Research, KS1	1	370	Teacher or Teaching Assistant, group	3.5		Brooks, 2007
Juel (1996)	Literacy tutoring	2 to 3	6	College Students	3.15		Elbaum, Vaughn, Hughes, & Moody, 2000
Nicolson, Fawcett & Nicolson (1999)	Interactive Assessment & Teaching (IA&T) (RITA)	3	16	Teachers/ Researchers and Computer	1.34	0.77	Singleton, 2009
Hempenstall (2008)	Corrective Reading: Decoding	5 to 7	206	Small Groups	1.22		Slavin, Lake, Davis, & Madden, 2009
Ehri et al. (2007)	Reading Rescue	1	102	Teachers	1.08		Slavin et al. 2009
Santa & Høien (1999)	Early Steps/ Howard Street Tutoring	1	49	Teachers	1.04		Slavin et al. 2009
Brown, Morris, & Fields (2005)	Early Steps/ Howard Street Tutoring	2 to 6	59	Teachers	1.03		Slavin et al. 2009
Nicolson et al. (1999)	Reader's Intelligent Teaching Assistant (RITA),	2	116	Computer & teacher, 1-1		0.98	Brooks, 2007
Foorman et al (1998)	Open Court	1	68	Class	0.91		Ehri, Nunes, , Stahl, & Willows, 2001
Torgesen, Wagner, & Rashotte 1997	Auditory Discrimination in Depth	2	65	Teachers	0.90		Slavin et al. 2009
Ehri et al. (2007)	Reading Rescue	1	96	Paraprofessionals	0.89		Slavin et al. 2009

Studies	Intervention Study/Programme	Year Group	Sample Size	Taught by	Effect Size		Source
					Reading Accuracy	Spelling Accuracy	
Primary Level							
Meier & Invernizzi (2001)	Book Buddies	1	55	Volunteers	0.89		Slavin et al. 2009
Center, Wheldall, Freeman, Outhred, & McNaughton (1995)	Reading Recovery	1	56	Teachers	0.86		Slavin et al. 2009
Morris, Tyner, & Perney (2000)	Early Steps/ Howard Street Tutoring	1	86	Teachers	0.86		Slavin et al. 2009
Blachman, Schatschneider, Fletcher, Francis, Clonan, Shaywitz, & Shaywitz (2004	Intensive Reading Remediation	2, 3	69	Teachers	0.85		Slavin et al. 2009
Blachman, et al (1999)	Blachman PA (Phon. Awareness)	Kindergarten	159	Small Group	0.72		Ehri et al. 2001
Vadasy, Sanders, & Peyton (2005)	Sound Partners	1	57	Paraprofessionals	0.71		Slavin et al. 2009
Lovett et al. (2000)	Empower Reading	1 to 4	37	Small Groups	0.71		Slavin et al. 2009
Knapp and Winsor (1998)	Cognitive apprenticeship in reading	2 to 3	8	Teachers	0.71		Elbaum et al. 2000
Jenkins, Peyton, Sanders, & Vadasy (2004)	Sound Partners	1	99	Paraprofessionals	0.69		Slavin et al. 2009
Hatcher, Hulme et al. (2006)	Reading Intervention	1	77	Teaching assistants	0.69		Singleton, 2009
McCarthy, Newby, and Recht (1995)	Early Intervention Program	1	19	Teachers	0.68		Elbaum et al. 2000
Martinussen & Kirby (1998)	Successive phonics	Kindergarten	26	Small Group	0.62		Ehri et al. 2001
Fawcett, Nicolson, Moss, Nicolson & Reason (2001)	Interactive Assessment & Teaching (IA&T)	3	36	Teachers/ Researchers	0.61	0.72	Singleton, 2009

Studies	Intervention Study/Programme	Year Group	Sample Size	Taught by	Effect Size		Source
					Reading Accuracy	Spelling Accuracy	
Primary Level							
Nicolson, Fawcett & Nicolson (1999)	Interactive Assessment & Teaching (IA&T) (also within RITA) (Fawcett)	2	98	Teachers, group		0.56	Brooks, 2007
Greaney et al. (1997)	RRD-Rime analogy	2 to 5	34	Class	0.56		Ehri et al. 2001
Brown et al. (2005)	Howard Street Tutoring	1	63	Paraprofessionals	0.55		Slavin et al. 2009
Oakland et al (1998)	Orton-Gillingham	6	48	Small Group	0.54		Ehri et al. 2001
Vadasy, Sanders, & Tudor (2007)	Sound Partners	2 to 3	43	Paraprofessionals	0.52		Slavin et al. 2009
Bond et al. (1995-96)	Sing, Spell, Read, Write	Kindergarten	144	Class	0.51		Ehri et al. 2001
Baker, Gersten, & Keating (2000)	Start Making a Reader Today (SMART)	1 to 2	84	Paraprofessionals	0.5		Slavin et al. 2009
Mathes et al. (2005)	Proactive Reading	1	162	Small Groups	0.49		Slavin et al. 2009
Hurry, J., Nunes, T., Bryant, P., Pretzlik, U., Parker, M., Curno, T. and Midgley, L. (2005)	Improving Spelling through Teaching Morphemes	5	686	Teachers, group		0.49	Brooks, 2007
Nicolson, Fawcett & Nicolson (1999)	Interactive Assessment & Teaching (IA&T) (also within RITA) (Fawcett)	3	87	Teachers, group		0.44	Brooks, 2007
Bond et al. (1995-96)	Sing, Spell, Read, Write	2	320	Class	0.38		Ehri et al. 2001
Greaney et al. (1997)	RRD-Rime analogy	2 to 5	36	Class	0.37		Ehri et al. 2001
Hatcher, Hulme and Ellis (1994)	Reading Intervention	2	32	Teachers	0.36	0.36	Singleton, 2009
Foorman et al (1998)	Embedded (Embedded Phonics)	1	70	Class	0.36		Ehri et al. 2001

Studies	Intervention Study/Programme	Year Group	Sample Size	Taught by	Effect Size	Source

					Reading Accuracy	**Spelling Accuracy**	
Gunn et al. (2005)	Schools and Homes in Partnership (SHIP)	3	211	Small Groups	0.34		Slavin et al. 2009
Bowyer-Crane et al. (2008)	Phonology with Reading	Reception	152	Teaching assistants/Group	0.32	0.45	Singleton, 2009
Mathes et al. (2005)	Responsive Reading	1	165	Small Groups	0.31		Slavin et al. 2009
Ehri et al. (2007)	Voyager Passport	1	122	Small Groups	0.31		Slavin et al. 2009
Foorman et al (1997)	Orton-Gillingham	2 to 3	67	Small Group	0.27		Ehri et al. 2001
Hurry & Sylva (2007)	Reading Recovery	2	389	Teachers	0.26		
Bond et al. (1995-96)	Sing, Spell, Read, Write	1	276	Class	0.25		Ehri et al. 2001
Vadasy & Sanders (2008)	Quick Reads	2 to 3	162	Small Groups	0.22		Slavin et al. 2009
Vadasy & Sanders (2008)	Quick Reads	4 to 5	119	Small Groups	0.20		Slavin et al. 2009
Pinnell et al (1994)	Reading Recovery	1	193	Teachers	0.19		Slavin et al. 2009
Wang & Algozzine (2008)	Targeted Intervention	1	139	Small Groups	0.19		Slavin et al. 2009
Foorman et al (1998)	Open Court	2	35	Class	0.12		Ehri et al. 2001
Foorman et al (1998)	Embedded	2	57	Class	0.03		Ehri et al. 2001
Marston et al (1995)	Direct Instruction	1 to 6	53	Class	0.01		Ehri et al. 2001
Foorman et al (1997)	Onset-rime	2 to 3	85	Small Group	-0.11		Ehri et al. 2001
Secondary							
Lingard, A.W. (1996a)	Literacy Acceleration in Cornwall	7	40	Other Adults 1-1	1.14		Brooks, 2007
Lingard, A.W. (1996a)	Literacy Acceleration, 2nd cohort	7	38	Other Adults, 1-1	0.62		Brooks, 2007
Vollands et al. (1999)	The Accelerated Reader, group 1	7	47	Computer & teacher, 1-1	0.55		Brooks, 2007
Ramaswami: Sample 1 (1994)	Reading Recovery	1	12	Teachers	2.17		Elbaum et al. 2000
Stepien, D. (1997)	Family Literacy in Hampshire	Reception	515	Other adults, group	1.91		Brooks, 2007
Burroughs-Lange, S. (2006)	Reading Recovery, Every Child a Reader (ECaR) in London, BAS	1	234	Teachers, 1-1	1.30/1.50a		Brooks, 2007
Non-Journal Articles	**Intervention Study/Programme**	**Year Group**	**Sample Size**	**Taught by**	**Effect Size**		**Source**
					Reading Accuracy	**Spelling Accuracy**	

Primary							
Ramaswami: Sample 2 (1994)	Reading Recovery	1	5	Teachers	1.2		Elbaum et al. 2000
Worsley, J. (2001)	Catch Up Literacy, pilot, experimentals in matched schools	3	1284	Teacher or Teaching Assistants, 1-1	0.97		Brooks, 2007
Torgesen et al. (2009)	Lindamood Phoneme Sequence Program-Small Group	1	74	Small Groups	0.66		Slavin et al. 2009
Brooks (2007)	AcceleRead AcceleWrite	3-9	61	Teachers/ Teaching assistants	0.55	0.27	Singleton, 2009
Norgate and Bentote (2005)	Screening and Intervention for Dyslexia, Notably in the Early Years (SIDNEY)	2	66	Teaching assistants	0.43		Singleton, 2009
Torgesen et al. (2009)	Read, Write, and Type-Small Group	1	73	Small Groups	0.36		Slavin et al. 2009
Lafave (1995)	Reading Recovery	1	23	Teachers	0.36		Elbaum et al. 2000
Ramaswami: Sample 3 (1994)	Reading Recovery	1	19	Teachers	0.35		Elbaum et al. 2000
Vernon-Feagans, Amendum, Kainz, Ginsberg, & Bock (2009) Study 2	Targeted Reading Intervention	1	151	Teachers	0.34		Slavin et al. 2009
Heistad (2005)	Read Naturally	3 and 5	102	Small Groups	0.27		Slavin et al. 2009
Vernon-Feagans, Amendum, Kainz, Ginsberg, & Bock (2009) Study 1	Targeted Reading Intervention	1	125	Teachers	0.25		Slavin et al. 2009
Lovett et al. (2008)	Empower Reading	2 to 8	166	Small Groups	0.25		Slavin et al. 2009

Non-Journal Articles	Intervention Study/Programme	Year Group	Sample Size	Taught by	Effect Size		Source
					Reading Accuracy	Spelling Accuracy	
Mayfield (2000)	Edmark Reading Program	1	60	Paraprofessionals	0.23		Slavin et al. 2009
Torgesen et al. (2006, 2007)	Spell Read	3 and 5	196	Small Groups	0.17		Slavin et al. 2009
Torgesen et al. (2006, 2007)	Wilson Reading	3 and 5	158	Small Groups	0.17		Slavin et al. 2009
Torgesen et al. (2006, 2007)	Corrective Reading: Decoding	3 and 5	165	Small Groups	0.16		Slavin et al. 2009
Morrow-Howell, et al. (2009)	Experience Corps	1 to 3	881	Volunteers	0.11		Slavin et al. 2009
Torgesen et al. (2006, 2007)	Failure Free Reading	3 and 5	219	Small Groups	0.05		Slavin et al. 2009
Lesnick (2006)	New Heights Reading Program	3 and 5	233	Small Groups	0.02		Slavin et al. 2009
Gottshall (2007)	Gottshall Small Group Phonics	1	64	Small Groups	-0.1		Slavin et al. 2009
Curry, Griffith, & Williams 1995	Reading Recovery	1	553	Teachers	-0.16		Slavin et al. 2009
Ramaswami: Sample 4 (1994)	Reading Recovery	1	13	Teachers	-0.37		Elbaum et al. 2000
McGrady (1994)	Programed [sic] tutoring	4 to 6	35	No information	-0.37		Elbaum et al. 2000
Chapman, Tunmer, and Prochnow: Sample 1 (1998)	Reading Recovery	1	26	Teachers	-0.43		Elbaum et al. 2000
Chapman, Tunmer, and Prochnow: Sample 2 (1998)	Reading Recovery	1	6	Teachers	-1.32		Elbaum et al. 2000
Secondary							
Parkinson (Unpublished 2004-05)	Sound Training for Reading	9	91	Teacher, group	0.65		Brooks, 2007
Lewis, A. (1995)	Integrated Learning Systems (ILS), Phase II, School M	7-9	'Several hundred'	Computer & teacher, 1-1	0.60		Brooks, 2007

Note. Exps = members of an experimental group. a 1st effect size calculated from standardised scores, 2nd from reading age.

Table A8

Summary of Intervention Studies in Decreasing Order of Ratio Gain.

Studies	**Intervention Study/Programme**	**Year Group**	**Sample Size**	**Taught by**	**Ratio Gain**		**Source**
					Reading Accuracy	Spelling Accuracy	
Primary							
Hatcher (2000b)	Reading Intervention	2–10	29	Teachers	2.9	2.1	Singleton, 2009
Hatcher (2000b)	Reading Intervention	2–10	427	Teachers	2.0	2.6	Singleton, 2009
Hatcher, Hulme and Ellis (1994)	Reading Intervention	2	32	Teachers	1.5	1.7	Singleton, 2009
Secondary							
Lingard, A.W. (1996a)	Literacy Acceleration, 1st cohort	7–8	15	Other adults, 1-1		2.0	Brooks, 2007
Lingard, A.W. (1996a)	Literacy Acceleration, 2nd cohort	7	26	Other adults, 1-1		1.6	Brooks, 2007
Non-Journal Articles							
Primary							
Brooks (2007)	AcceleRead AcceleWrite	5–6	30	Teachers/ Teaching assistants	16.9	9.8	Singleton, 2009
Brooks (2007)	AcceleRead AcceleWrite	3-9	61	Teachers/ Teaching assistants	8.3	4	Singleton, 2009
Derrington (2001a, 2001b)	Phono-Graphix	2-6	74	Teachers	8.3	3.3	Singleton, 2009
Matthews (1998)	Teaching Handwriting, Reading and Spelling Skills (THRASS)	3-6	160	Teachers/Teaching assistants	2.6	1.2	Singleton, 2009
Bristol Learning Support Service (2005)	AcceleRead AcceleWrite	2-6	60	Teachers/ Teaching assistants	2.3	2.0	Singleton, 2009
Brooks (2007)	Read Write Inc	2–6	117	Teachers/Teaching assistants/Group	2.3	1.7	Singleton, 2009
Secondary							
Lanes et al. (2005)	Read Write Inc. Fresh Start in Cornwall	7	63	Teacher, group	8.0		Brooks, 2007
Matthews (1998)	Teaching Handwriting, Reading and Spelling Skills (THRASS)	8	76	Teacher, group	5.3		Brooks, 2007
Taylor, C. (2000)	Better Reading Partnerships (BRP) in Derbyshire	8	57	Other adults, 1-1	5.0		Brooks, 2007
Matthews (1998)	Teaching Handwriting,	7–8	76	Teachers/Teaching assistants	4.3	1.9	Singleton, 2009

	Reading and Spelling Skills (THRASS)						
Taylor, C. (2000)	BRP in Derbyshire	7	132	Other adults, 1-1	4.1		Brooks, 2007
Matthews (1998)	Teaching Handwriting, Reading and Spelling Skills (THRASS)	8	76	Teacher, group		2.0	Brooks, 2007
Matthews (1998)	Teaching Handwriting, Reading and Spelling Skills (THRASS)	7	76	Teacher, group	4.0	1.8	Brooks, 2007
Lanes et al. (2005)	Read Write Inc	7	63	Teachers/Teaching assistants/Group	2.3	0.8	Singleton, 2009
Brooks, Harman and Harman (2003)	Read Write Inc	7–9	156	Teachers/Teaching assistants/Group	1.6	0.9	Singleton, 2009
Brooks et al. (2003)	Read Write Inc. Fresh Start, DfES study	7-9	252	Teacher, group		0.9	Brooks, 2007

Table A9
List of Reading Interventions Studies.

Studies	No. Articles Reviewed	Criteria Method
Elbaum, B., Vaughn, S., Hughes, M. T., & Moody, S. W. (2000). How effective are one-to-one tutoring programs in reading for elementary students at risk for reading failure? A meta-analysis of the intervention research. Journal of Educational Psychology, 92, 605-619. Criteria 2	31	(1) Study published between 1975 and 1998. (2) Elementary school participants identified as at risk for reading failure. (3) Outcomes of students who received one-to-one instruction were compared to those of students with low performance in reading who did not receive one-to-one instruction. (4) Outcome data amenable to the calculation of an effect size.
Scammacca, N., Vaughn, S., Roberts, G., Wanzek, J., & Torgesen, J. K. (2007). Extensive reading interventions in grade k–3: From research to practice. Portsmouth, NH: RMC Research Corportation, Center on Instruction. Criteria 2.	12	Reviewed intensive intervention studies with children with LD or at risk for reading difficulties in kindergarten to grade 3 'Intensive' was defined as 100 sessions or more studies were required to employ a control or comparison group and contain data that allowed calculation of effect sizes
Vaughn, S. & Roberts, G. (2007) Secondary interventions in reading: Providing additional instruction for students at risk. Teaching Exceptional Children, 39, 40-46.		Summarised the elements of successful secondary reading interventions. These authors also stress the importance of providing explicit, systematic, targeted instruction 3-5 times a week including ample practice opportunities with immediate feedback.
Slavin, R. E., Lake, C., Chambers, B., Cheung, A., & Davis, S. (2009). Effective reading programs for the elementary grades: A best-evidence synthesis. Review of Educational Research, 79, 1391-1466.	96	The studies evaluated specific, potentially replicable programs for children who are having difficulties learning to read in grades K-5. The included studies compared children taught using a given reading program to those in a control group taught using an alternative program or standard methods. Studies could have taken place in any country, but the report had to be available in English. Random assignment or matching with appropriate adjustments for any pretest differences (e.g., analyses of covariance) had to be used. Pretest data had to be provided. The dependent measures included quantitative measures of reading performance, such as standardized reading measures. A minimum study duration of 12 weeks was required. Studies had to have at least 15 students and two teachers or tutors in each treatment group.
Brooks, G. & National Foundation for Educational Research (2007). What works for pupils with literacy difficulties? Department for Children, Schools and Families.	48	Quantitative evaluation data from the UK covering at least one year group and designed to boost reading and/or spelling and/or writing.

Singleton, C. (2009). Intervention for Dyslexia. Retrieved from http://www.thedyslexia-spldtrust.org.uk/3/latest-news/14/review-of-international-research-published-by-dr-chris-singleton/.	100+	Randomised control trial (RCT). Measures of performance or ability should be made at the outset of the study (pre-test) at the end of the study (post-test) and possibly at some later time (delayed post-test or follow-up). The persons delivering the intervention and those administering post-tests should, as far as possible, be 'blind' regarding which group they are working with.