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 Foresight

**Mental Capital and Wellbeing:  
Making the most of ourselves in the 21st century**

**State-of-Science Review: SR-D2  
Dyslexia**

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Mental Capital and Wellbeing. The views expressed do not represent the policy of  
any Government or organisation.*

## Summary

Starting from a consensus definition of dyslexia, this review summarises what is known about the nature and prevalence of the condition and its behavioural manifestations in different languages and across the life-span. It briefly outlines brain-based, perceptual theories of dyslexia before focusing on the widely agreed view that dyslexia is a language-based disorder characterised by deficits in phonological (speech) processing skills. A developmental framework is used to argue that impairments in phonological processing skills of likely genetic origin compromise reading acquisition and therefore pose a major risk factor for dyslexia. Further, it is argued that this risk is modulated by the availability (or otherwise) of proficient cognitive abilities, such as good oral language skills and attentional resources. Studies of children at high risk of dyslexia, by virtue of having a first degree affected relative, are reviewed to highlight precursors of dyslexia during the pre-school years and to corroborate diagnostic indicators. Such studies also emphasise the view that dyslexia is not an 'all-or-none' condition, but a dimensional disorder without clear boundaries or diagnostic criteria. The final section of the review provides an overview of effective interventions that ameliorate the symptoms of dyslexia whilst noting that there is considerable variation in children's response to such interventions. Those who carry a heritable risk of dyslexia may be the hardest to teach.

## 1. Dyslexia in context

Dyslexia presents a major obstacle to educational success in about 7% of schoolchildren that can begin a downward spiral of underachievement, low self-esteem, poor mental health and social disadvantage. Although there has been 40 years of scientific research on dyslexia (Vellutino et al., 2004), children with this condition are not systematically supported:

*"The system that exists today in schools is failing the dyslexic child; there is too much red tape, too many people who say they know what is needed to help and they don't, and it is pot luck if the intervention is delivered consistently to actually do any good"*

(Father of a child with dyslexia).

Most authorities agree that dyslexia is a neurobiological disorder

*'..characterised 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'*

(International Dyslexia Association, 2002).

Dyslexia often co-occurs with one or more other developmental disorders (e.g. developmental coordination disorder or attention deficit hyperactivity disorder, with up to 40% so affected), and there is a 2.7 fold increase in the incidence of anxiety disorders in this population. The presence of such co-morbidities complicates the behavioural manifestations of dyslexia and affects outcomes.

## 2. Incidence

The incidence of dyslexia depends on the criteria used to define the disorder. Boys are at greater risk of reading difficulties than girls, with sex ratios of between 1.5:1 and 3:1 males: females (Rutter et al., 2004).

In English-speaking countries dyslexia affects 4% to 8% of school-aged children. However, rates of reading disability vary with age.

Children identified at different ages may have differing patterns of cognitive deficit: word decoding problems predominate in the early school years; later, some poor readers who decode well experience reading comprehension problems. During adolescence and adulthood, individuals who have overcome early reading difficulties still face problems with spelling or written expression.

### 3. Nature of dyslexia

Learning to read requires the child to understand how letters of printed words relate to sounds of spoken words. In order to abstract this *alphabetic principle*, the child must be able to segment the sound structure of words, an ability referred to as *phonological awareness*, for example, deciding which is the odd one out in a set of rhyming words (e.g. sock, lock, moat, frock), or deleting a sound from a nonword to give a word (*bice* – /b/ is ‘ice’). Once they have acquired this principle, children read and write using a ‘phonic’ approach. However, English contains many words with irregular spellings that take years to master.

The challenge is less marked for readers of ‘regular’ writing systems in which letter-sound correspondences are predictable with few exceptions. Regardless of the language that has to be learned, fluent reading is required if reading comprehension is to be adequate. Dyslexia is associated with poor reading fluency in all languages, placing people with the disorder at risk of reading comprehension problems.

Table 1 summarises the primary presenting characteristics of dyslexia at different ages. The tell-tale signs are visible early, yet typically children must wait until they have failed before their problems are identified (Appendix 1).

<b>Developmental phase</b>	<b>Symptoms of Dyslexia</b>
<b>Preschool</b>	<ul style="list-style-type: none"> <li>• Delayed speech</li> <li>• Poor expressive language</li> <li>• Poor rhyming skills</li> <li>• Little interest/difficulty learning letters</li> </ul>
<b>Early school years</b>	<ul style="list-style-type: none"> <li>• Poor letter-sound knowledge</li> <li>• Poor phoneme awareness</li> <li>• Poor word attack skills</li> <li>• Idiosyncratic spelling</li> <li>• Problems copying</li> </ul>
<b>Middle school years</b>	<ul style="list-style-type: none"> <li>• Slow reading</li> <li>• Poor decoding skills when faced with new words</li> <li>• Phonetic spelling</li> </ul>
<b>Adolescence and adulthood</b>	<ul style="list-style-type: none"> <li>• Poor reading fluency</li> <li>• Slow speed of writing</li> <li>• Poor organisation and expression in written work</li> </ul>

**Table 1.** *Developmental phases of dyslexia.*

Beyond literacy, people with dyslexia experience other difficulties that affect their behaviour in educational settings. These include:

- Poor verbal short term memory.
- Poor new word learning (affects second language learning and learning of subject-specific vocabulary, such as terms used in biology).
- Difficulty in meeting deadlines (often because of slowness in working).
- Forgetting appointments, such as tutorials.

In less auspicious circumstances (e.g. where school and family supports are limited), reading disorders adversely affect educational progress, and attitudes to schooling suffer as a result. Many poor readers become disengaged from education and there are risks of unexplained absence and truancy, with some young people opting to leave school at the earliest opportunity, with minimal qualifications (Maughan, 1995). Others may become involved with the criminal justice system, as evidenced by the rates of low literacy in the prison population<sup>1</sup> (50%).

Dyslexia in the workplace can also be stressful, not only because of literacy demands, but because of associated difficulties, such as with working memory, organisation and time management. Many adults prefer not to disclose their dyslexia to employers. In such cases, disciplinary action or dismissal is the worst scenario, and some 4% of people with dyslexia spend more than 10% of their economically active lives unemployed (Maughan, personal communication).

## 4. Aetiology

### 4.1 Genetic factors

Prospective studies following the development of children born to parents with dyslexia reveal a heightened risk of literacy impairment. However, families share environments as well as genes, making it difficult to disentangle the contribution of genetic *versus* environmental factors on reading behaviour. Twin studies of dyslexia get around this problem to some extent. Typically, these find that reading is highly heritable (Pennington and Olson, 2005).

However, some of the shared genetic variance between twins may be due to gene-environment correlation. The home literacy background provided by more literate parents may foster reading skills, and better readers may themselves actively seek out more literary experiences (Snowling et al., 2007).

Progress has been made in understanding the molecular basis of genetic influences on reading (Fisher and DeFries, 2002; Paracchini et al., 2006). To date, the strongest evidence for linkage with dyslexia is a site on the short arm of chromosome 6, with others replicated on chromosomes 1, 2, 3, 11, 15 and 18 (Grigorenko, 2005). Recently, candidate susceptibility genes have been identified within these chromosomal regions, but it is important to emphasise that genetic influences are probabilistic. Complex disorders depend on the combined influence of many genes of small effect, as well as on environmental influences.

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<sup>1</sup>Using a narrow research definition of dyslexia, 20% of offenders are affected.

## 4.2 Brain bases

Early neurodevelopmental abnormalities appear to be involved in the condition. There is a wide range of structural brain differences between people with dyslexia and controls (Eckert, 2004). An 'anatomical risk index' comprising measurements taken from the brain regions implicated in dyslexia distinguishes between people with specific decoding difficulties and those with poor reading comprehension (Leonard et al., 2006).

Functional brain imaging studies during reading indicate that children and adults with dyslexia typically show less activity than controls in left hemisphere temporo-parietal regions (Price and McCrory, 2005). Preliminary evidence suggests that intervention may reduce this under-activation (Simos et al., 2002; Shaywitz et al., 2004). However, the causal status of brain differences in dyslexia is debatable because brain development shows considerable plasticity: both its structure and function are shaped by use.

## 4.3 Psycho-social influences

School and home environmental factors contribute to a child's risk of developing dyslexia. Reading disorders show a strong social gradient with poor readers often coming from large families. Where parents themselves have literacy problems, they may provide less than optimal reading-related experiences in the home (though in practice many parents with dyslexia are acutely aware of the need to support their children's literacy development; see Appendix 2).

Reading disorders primarily become apparent at school, and school experiences are influential. If texts are too difficult, reading becomes an unrewarding experience, and the cumulative impact of such processes leads to huge variations in children's 'exposure to print' which has an independent effect on reading progress.

## 5. Theories of dyslexia

The predominant theoretical account of dyslexia views its primary cognitive cause as a phonological processing impairment. According to this hypothesis, children with dyslexia have poorly specified phonological representations (Snowling, 2000; Swan and Goswami, 1997). That is, the part of their language system that maps between word meanings and speech sounds is impaired.

Deficits in phonological representation explain why people with dyslexia have difficulties with tasks that engage phonological processes. The most consistently reported difficulties are poor verbal, short-term memory and impaired phonological awareness.

Various theories have implicated deficits in low-level visual or auditory processing. Although research findings are mixed, and typically only a proportion of people with dyslexia are affected, it is difficult to interpret current data given that studies have been done at a late developmental stage when such deficits could be compensated. A causal hypothesis that still needs testing is that low-level impairments in the preschool years may be developmental antecedents of the phonological deficits that underlie dyslexia.

## 6. Studies of high risk children

Studies of children at family-risk of dyslexia followed from the preschool years, both elucidate the precursors of dyslexia before formal reading instruction begins and highlight protective factors. In one such study, Snowling et al., (2003) followed 56 children from 3;09 until eight years. As expected, the rate of literacy impairments was elevated in the at-risk group. The children who were classified as 'dyslexic'

experienced delayed language development at 3;09 years. At six years, they had persisting oral language impairments and immature phonological awareness. In contrast, the high-risk but normally reading group was indistinguishable from controls on oral language tests. There were also similarities between reading-impaired and unimpaired high-risk children: both groups showed poorer letter knowledge and spelling skills at six years than controls, highlighting the genetic liability. This finding suggests that family risk of dyslexia is continuous rather than discrete, an argument that has also been proposed by Pennington and Lefly (2001) who found shared deficits between impaired and unimpaired children on a phoneme awareness task.

It is not appropriate, therefore, to think of 'dyslexia' as a discrete category of impairment. Some children are slow in the early stages of reading but may compensate to proceed to be normal readers. In fact, Lyttinen et al., (2006) have described four different developmental trajectories to literacy in a Finnish family-risk sample. In addition to those whose reading development was normal and those who show a typically discrepant profile (with selective reading impairment), some children followed a 'declining' trajectory in all skills domains and others a 'dysfluent' pathway with severe impairments in rapid naming. More research is required to clarify the different pathways by which children at-risk of dyslexia follow on the way to literacy.

## **7. Interventions**

It is now well established that intervention programmes to promote phonological skills in the context of reading are effective (Brooks, 2002; Torgesen, 2005). For children with dyslexia, such programmes are best delivered by trained teachers who understand how to tune a programme to a child's specific needs. The main elements of these approaches include: training in letter knowledge; phoneme awareness; applying letter and sound knowledge to word reading (phonics); reading text; and writing (linkage) activities.

Recently, this approach has been adapted for delivery by teaching assistants to small groups of Year 1 children with reading delay. Hatcher et al. (2006) demonstrated in a randomised, controlled trial that the approach is effective, with reading gains of, on average, .23 standard score points per hour of intervention. These findings converge with those of other research groups and have direct policy implications for the treatment of children with dyslexia (Appendix 3).

However, some children with dyslexia respond very slowly even to the most effective of teaching approaches (Hindson et al., 2005). An important issue is the problem of children who, despite high quality intervention, continue to have persistent reading impairments. These 'treatment non-responders' tend to have the most severe phonological deficits. They are often socially disadvantaged, with many experiencing emotional and behavioural difficulties. Because of the intractable nature of the disorder, some families turn to alternative or complementary therapies. There is no evidence that these therapies work. More generally, little is known about how best to help children who do not respond to conventional remediation. Best practice at the present time includes more intensive, multi-sensory teaching and placement in specially resourced units.

In contrast to what is known about how to teach poor readers, there is limited evidence regarding preventative programmes. Preliminary evidence suggests that theoretically motivated programmes to promote phonological skills and letter knowledge at school entry can bring the literacy skills of at-risk children to within the normal range (Appendix 3), but the longer-term impact of such interventions is unknown.

## 8. Conclusions and future advances

The nature and consequences of dyslexia are well-understood, but there is an urgent need to test causal hypotheses regarding the developmental nature of this disorder and its relationship to other language and learning impairments.

It is important to clarify the range of developmental trajectories that lead to severe and persistent reading impairments and the role of low-level perceptual impairments in these.

A more precise characterisation of the 'cognitive phenotype' in the pre-school years is needed to inform genetic and neurobiological research. Future advances in neurogenomics could, in turn, elucidate how susceptibility genes in interaction with different environmental experiences affect brain development in dyslexia. Such research will have important implications for early intervention.

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## **Appendix 1: A case study**

Johnny is the youngest of three sons born to a family in which there is a strong history of dyslexia on both sides. Because his parents were well aware of the genetic risk he carried, he was first assessed by an independent psychologist when aged 7 years 3 months (in 2002). This assessment indicated that Johnny was a boy of average intelligence whose strengths lie in the non-verbal sphere. On the British Ability Scales II he gained a spatial IQ of 114, a non-verbal reasoning IQ of 91 and a verbal IQ of 81. His cognitive profile was therefore indicative of language learning difficulties. At the time, Johnny was showing significantly delayed development of reading and spelling skills; his numeracy development was relatively better. Given the very strong family history of dyslexia, taken together with other at-risk signs, including his poor expressive language and phonological skills, it was considered that he was at high risk of under achievement and likely to be dyslexic.

In January 2003, Johnny was receiving two half-hour sessions per week of literacy support in school and, at home, he was reading every day with his parents. In addition, because of his slow progress, they decided, at their own expense, to send him for lessons at an independent dyslexia centre twice per week. This involved Johnny coming out of school and travelling for some 10 miles each way, a procedure that was disruptive to him and a considerable cost to his family.

Johnny's slow progress in literacy continued so that, in 2005, his parents requested that the local authority conduct a statutory assessment of his special educational needs. Although his school had put in place what resources it had, Johnny was failing to progress, so more intensive, specialist support was required. Johnny's parents had to proceed to an educational tribunal in order to obtain the required assessment. Although the local authority's assessors agreed that Johnny had severe and persistent dyslexia, they argued that his needs were not complex and could be accommodated within mainstream school. Johnny was now in Year 6. Extra support was, accordingly, provided by the local authority for his last term in primary school before transfer to secondary school.

On secondary school transfer, Johnny's difficulties were still marked, and his self-esteem low. For the first time, he was beginning to try to avoid attending school, in spite of extra support he was receiving in class, including two lessons a week with a teaching assistant. His parents returned to the tribunal to argue that he required specialist teaching, over and above that which he was receiving. A statement of special educational needs was finally issued some five years after Johnny's severe but specific learning difficulties were first identified. The specialist teaching he requires is still not properly in place, and Johnny has now himself decided he would like to go to a special school.

The table below shows his progress in literacy skills over the period in which he has been monitored. He remains significantly behind his peers in literacy and hence in many aspects of his schoolwork, although he is of average intelligence.

Date	11/02	3/04	10/05	7/06
Age	7;03	8;08	10;02	10;10
BASII Reading	82	77	76	75
TOWRE sight word efficiency		75	73	73
TOWRE phonemic decoding efficiency		73	75	85
NARAII Accuracy		73	<71	84
NARAII Comprehension		<74	72	82
BASII Spelling	77	75	66	-

Progress of a child with severe dyslexia through the primary school years (standard scores where 100 is average for the population; scores <75 indicate performance within the bottom 5% of the population of children of this age; scores < 85 indicate performance within the lowest 18% of the population).

## Appendix 2: Johnny's father

Johnny's father is dyslexic. He appreciates his son's difficulties. Below are extracts from notes he wrote for Johnny's teachers in order to help his son cope in class. In italics are Johnny's own comments.

### Johnny – Recommendations for differentiation

Johnny has been diagnosed as severely dyslexic and is statemented for these difficulties. His intelligence is good, but he has a number of processing difficulties that affect him adversely in an academic situation and mean that his results in most literacy-based tasks are unlikely to reflect his ability. He is likely to have visual strengths regarding his learning style. Close, continuous and consistent working links between the specialist teacher and all staff are essential if Johnny is to succeed. In summary his principal difficulties are:

- Limited sight vocabulary and very poor reading fluency.
- Inability to produce target words in phonic form reliably and poor fluency in writing.
- Slowness in committing ideas to paper.
- Weak computational skills.
- Word-finding difficulties.
- Poor planning and organisational skills.
- Inability to remember and understand oral instructions.

Please make homework manageable (breaking into smaller tasks).

*"It needs to be explained or I don't know how to do it properly."*

Stagger homework; if several tasks come together he becomes very stressed and angry. If this is unavoidable then give guidance as to which tasks have priority and consider extending deadlines on one or two others until he has regained control of his workload.

*“Yes! For History nearly every time we have a piece of homework. I have to waste my time doing stuff like maths or an essay and I don’t get time to do what I want to do.”*

Check that his homework in the planner has been accurately recorded and that he understands what he has to do and is aware of deadlines.

*“Some times they look, but mostly they don’t bother, and when I get home I can’t remember what I have to do.”*

When covering new vocabulary in lessons, ensure that he reads, understands and is able to use it in context. Liaise with Johnny’s specialist teacher and pass on new words.

*”I do find it difficult.”*

He should have at the start of the lesson, copies of all handouts and lesson notes for annotation.

*“I get these sometimes now and it’s good because I don’t have to keep looking up at the board.”.*

Use multi-sensory teaching techniques, presenting information in a variety of styles.

*“It makes it easier to understand, so I don’t always do the same thing. I find it easier to learn in pictures than in words.”*

Ensure that all photocopied sheets are no smaller than 12 pitch and of good quality that Johnny can read.

*”8 pitch I can’t see it!”*

If required to copy, make sure Johnny has finished before rubbing off the text from the board; also check it has been accurately copied down.

*”When I do copy I get words wrong and then they say I should have got it right.”*

If he asks for help, please check that he understands before moving on as he gets stuck.

*”I get stuck but nobody helps me. They just help the other people.”*

He needs extra time for writing.

*“I don’t know why but I do – it could be the spelling.”*

Internet searches take a long time so give named sites for research.

*“I can never find the information I am trying to find.”*

He is unable to write while you are speaking/dictating.

*”If this happens, like in History, it’s then I can’t keep up.”*

Reading aloud is very stressful. Please do not ask him to do so in a group setting.

*“It happened in a mini play. It made me really annoyed as I ended up doing the longest part. It’s really embarrassing as I stumble over words.”*

### **Appendix 3: Costs of intervention**

An important practical question is how far research findings generalise. To address this, North Yorkshire Educational Authority undertook an effectiveness trial of *Reading with Phonology* intervention. Fifty teaching assistants from 38 primary schools undertook a four-day training programme delivered by members of the local authority. The 'trainees' then delivered the reading intervention programme to 142 children, the majority being in Year 1. Children received on average 38 sessions in a 10-week period as a result of which they made over seven months progress in reading (Gibbs and Smith, personal communication).

Although it is impossible to be certain that the gains were due to the programme and not to the special attention these children received, the findings of this field trial increase confidence that *Reading with Phonology* is an effective approach for children with literacy difficulties (Primary National Strategy, 2006).

The overall costs for all children average out at £281.70 per child, £7.53 per session or £39 per month of progress per child.

A recent randomised controlled trial evaluating the effects of an intervention training phonology with reading at school entry significantly raised the early literacy skills of at-risk children when compared with an intervention focusing on the development of oral language (vocabulary, grammar and narrative skills) [http://www.york.ac.uk/res/crl/crl\\_Nuffield.html](http://www.york.ac.uk/res/crl/crl_Nuffield.html).

The direct costs of the 20-week intervention (payments to teaching assistants) were estimated at £500 per child.



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