

Aid to the Early Detection of Dyslexia

Final Report

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1.0	28/02/2002	Initial Version released to partners
2.0	17/04/2002	Report refined following DfES and partner reviews

Executive Summary

Children's experiences in the earliest years of their life are critical to their subsequent development. Their early years should be enjoyable, secure, but fun and full of challenge. They are a vital time when children develop rapidly – physically, intellectually, emotionally and socially. Earliest experiences of learning should be happy and positive so children are prepared for later education and training and have an equal opportunity to succeed.

To help ensure all children's experiences of education are positive and happy, it is important to enable the earliest identification of children with special educational needs, including those with specific learning difficulties such as dyslexia. The SEN (Special Educational Needs) Code of Practice 2001 places considerable emphasis on early intervention. The development of a tool that can assist the detection of dyslexia in children as young as four to five years of age would help to ensure that children with dyslexia receive appropriate intervention at an early stage in their education and help to give them every opportunity to succeed.

This report is the final deliverable of the Invest-To-Save Budget (ISB) third round seedcorn project (ISB project number 139) assessing the utility of eye-tracking technology to aid in the early detection of dyslexia in young children. There is currently no objective test for early detection although in recent times, both computerised and behavioural tests have been introduced to identify those young (4-5 years old) children at risk. As with a number of conditions, early recognition and skilled specialist teaching can alleviate the effects of dyslexia; there is therefore considerable benefit in the earliest possible detection.

The project is a collaboration between:

- DfES;
- QinetiQ;
- Oxford University Physiology Department;
- The Dyslexia Research Trust Learning Difficulties Clinic;
- Hampshire LEA.

In support of the need for early identification, the Department for Education and Skills (DfES) through the Government's ISB initiative funded a £100K project announced in the 2nd reading of the SEN and Disability Bill (now SEN and Disability Act 2001). The aim is to investigate the development of a prototype design for a portable, child-friendly, early diagnostic tool for specific learning difficulties that may be caused by impaired visual transient process (eye wobble). The project was initiated in recognition of how this partnership could benefit from military capability that permitted researchers to see video of the pilot's view overlaid with an indicator of where he is looking. Prior to this phase the seedcorn project has scoped the activity recommending that the project:

- develop a new test, correlated with existing procedures, to support the school/carers in early assessment for dyslexia;
- ensure that this innovative solution is suitable for use with young children from the requirements of safety, ergonomics and scientific validity;

- identify the user requirements from the point of view of the child, teacher, SENCO, carer and researcher;
- capture these user needs in a system requirement specification that will develop a fuller understanding of how current technology could meet these needs.

This was followed by a series of activities in direct response to those recommendations leading to a report covering the work and findings of the User Requirements Capture exercise. This task of defining the requirement for using an eye tracker in a school environment has formed the main part of this project.

The recordings that were obtained with this new design have been outstandingly successful. In particular the ease of calibration has meant that the team has already been able to make good recordings in 4-5 year olds. These pilot results have clearly shown that the system works with small children, it can be used easily, and the recordings can be successfully analysed.

At present the spectacle-mounted system is still rather heavy for young children and further work is required to make it lighter. Furthermore at present it can only measure the movements of one eye, whereas many of dyslexics' visual difficulties are the result of their vergence deficiencies. Hence future work is needed to duplicate the system for measurement of the movements of both eyes. Finally at present the computation of the moment-to-moment position of the eyes is slow and cannot be carried out on line. However modern dedicated processors are fast enough to carry out the necessary calculations, with further software development.

The final phase of the project has been to develop an outline design meeting the user needs and providing input for future developments. The ISB project has successfully demonstrated that the novel partnership between government, LEAs and research organisations can provide genuine benefit to meet the requirement to recognise and remediate the dyslexic child as early as possible.

Consequently, it is possible to adapt the equipment designed for fast jet pilots for use with children to test the validity of the magnocellular theory in future research with the objective of identifying a tool that can help recognise certain dyslexics early on.

In order to realise the recommendations and to provide objective evaluation of the validity of early detection of visual reading difficulties with dyslexia, there is a need for controlled research trials. It is proposed that such a project would enable descriptions of young children's dyslexic profile, eye movement behaviour and validation of the 'eye wobble' theory through a series of stages. The research would be conducted in the school setting enabling further testing of the usability of the eye recording system. The aim will be to develop a system that can be properly and objectively assessed in terms of:

- its value/impact as a means of early identification of dyslexia;
- user-friendliness (child users and adults who have to administer);
- its relationship to other early screening tests/means of early identification of dyslexia;
- and how the system might contribute to wider early intervention strategies.

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1 Introduction

1.1 Background

1.1.1 Children's experiences in the earliest years of their life are critical to their subsequent development. Their early years should be enjoyable, secure, but fun and full of challenge. They are a vital time when children develop rapidly – physically, intellectually, emotionally and socially. Earliest experiences of learning should be happy and positive so children are prepared for later education and training and have an equal opportunity to succeed.

1.1.2 To help ensure all children's experiences of education are positive and happy, it is important to enable the earliest identification of children with special educational needs, including those with specific learning difficulties such as dyslexia. The Special Educational Needs (SEN) Code of Practice 2001 places considerable emphasis on early intervention. The development of a tool that can assist the detection of dyslexia in children as young as four to five years of age would help to ensure that children with dyslexia receive appropriate intervention at an early stage in their education and help to give them every opportunity to succeed.

1.1.3 Dyslexia comes from two Greek words that together mean 'difficulty with words'. Dyslexia affects reading, spelling, writing, memory and concentration and sometimes maths, music, foreign languages and self-organisation. Dyslexia is considered to be a specific learning difficulty and its cause and treatment has been researched and discussed for many years. "Dyslexia is a complex neurological condition which is constitutional in origin. The symptoms may affect many areas of learning and function, and may be described as a specific difficulty in reading, spelling and written language" (British Dyslexia Association, 1995).

1.1.4 Singleton (2000)¹ defines the key cognitive characteristics of dyslexia as being:

- inadequate phonological processing abilities;
- a marked inefficiency in working memory;
- difficulties in automatising skills, e.g. driving a car, reading;
- problems that are related to visual processing, e.g. visual discomfort associated medical conditions.

1.1.5 In summary,

" Dyslexia is best described as a combination of abilities and difficulties which affect the learning process in one or more of reading, spelling, writing and sometimes numeracy/language. Accompanying weaknesses may be identified in areas of speed of processing, short-term memory, sequencing, auditory and/or visual perception, spoken language and motor skills. Some dyslexics have outstanding creative skills. Others have strong oral skills. Whilst others have no outstanding talents, they all have strengths. Dyslexia occurs despite normal intellectual ability and conventional teaching. It is independent of socio-economic or language background."

(British Dyslexia Association, 2002²)

¹ Source Dr Chris Singleton, June 2000 Guest Article, Understanding Dyslexia: Introductory Notes, <http://www.devdis.com/gueststart-jun.html>

² Source www.bda-dyslexia.org.uk
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1.1.6 Dyslexia occurs in people from all backgrounds and of all abilities, from people who cannot read or write to those with university degrees. It tends to run in families and continues throughout life, with around 4% of the population severely affected and a further 6% with mild to moderate problems. It seems to be more common in males than females (Singleton, 2000). Once correctly diagnosed, strategies for improvement and coping with their areas of difficulty can be developed but dyslexia does not 'go away'.

1.2 ISB 3

1.2.1 "In the White Paper " Modernising Public Services for Britain - Investing in Reform", the Government stated its intention to deliver public services in a more integrated and co-ordinated way. A number of new programmes pursuing cross-departmental objectives and joint working arrangements were put in place to take this forward. One of these new initiatives was the Invest to Save Budget (ISB) which was created to help develop projects which bring together two or more public service bodies to deliver services in an innovative and more efficient fashion. The ISB is designed to encourage such bodies to work more closely together and identify projects that would not otherwise go ahead. In this way, the ISB supports the programme for delivering better public services through "joined-up government" set out in the Modernising Government White Paper published on 30 March 1999."³

1.2.2 The objective of this ISB3 project was to conduct an investigation into an early diagnostic tool for childhood dyslexia that would enable advanced military technology to be applied to educational screening for recognised visual indicators. Eye tracking research in QinetiQ has led to the development of technology and a prototype system intended for use in the hostile operating environment of military fast-jet aircraft. The performance targets already attained by the Interleaved Scene and Eye Camera Spectacles (ISECS) system, in the extremely harsh conditions encountered by a military pilot, minimise the design risk of any proposed system for a classroom or clinical environment. Complex issues relating to methods of operation, repeatability, reliability, and portability have already been comprehensively studied. The project needed to identify how the lessons that QinetiQ had learned in the development of this system would be linked to appropriate age based assessments, would be child friendly and would meet appropriate standards.

1.2.3 In support of this recognition, the DfES through the Government's ISB initiative has funded this project announced in the SEN 2nd Reading of the SEN and Disability Bill (now the SEN and Disability Act 2001). This pilot project proposed, under the umbrella of the DfES, a union of QinetiQ eye tracking technology and scientific knowledge with the existing body of knowledge of dyslexia represented by Prof John Stein and supported by the Dyslexia Research Trust.

1.3 Eye Tracking Technology

1.3.1 Scientists at QinetiQ have had a long-standing interest in understanding what operators looked at and testing whether it was possible to use eye pointing for such tasks as controlling computers and aiming weapons. The team particularly wanted to measure the line of gaze of military pilots in combat aircraft. This presented a series of problems: difficult equipment installation, minimal disturbance to the pilot's vision, compatibility with aircrew protective equipment, the harsh level of incident sunlight, and the possibility of

³ Invest To Save Budget: Round 3 - Bidding Guidance, <http://www.isb.gov.uk>

ejection in emergencies. In order to meet these requirements much effort and time has been spent by specialists to design and test a portable, reliable, rugged eye tracking system. To achieve this, the QinetiQ scientific team has reviewed a number of potential approaches. As a result of the military requirement the QinetiQ team have developed a unique eye tracking solution appropriate for the hazardous flight environment.

- 1.3.2 Jarrett and colleagues concluded that the best approach would be to develop a specialised set of equipment based on the well-proven 'differential CR/pupil' technique. In this, a head-mounted video camera collects an infra-red image of the eye, and the pilot's direction of gaze is then measured by finding the centre of the pupil and the bright spot produced by reflection of the infra-red illumination from the convex cornea. As with most tracking systems the team wanted to show the pilot's shifting direction of gaze as a marker on the video image of the scene in front of the subject. This was obtained from another head-mounted video camera.
- 1.3.3 Both the eye camera and the aligned scene camera had to be placed close together near one eye in a safe, lightweight assembly. The QinetiQ team designed a compact unit that could either be attached to a flying helmet or be worn as a pair of spectacles. Hence the acronym ISECS. Analysis of the eye image and calibration was done off-line by replaying the recordings into the PC-based Point Of Regard Tracker (PORT) which QinetiQ had developed in conjunction with King's College London. The ISECS spectacle could also be coupled directly to PORT to measure eye-pointing direction for real-time interactions in simulation experiments.



Figure 2-1: The Pilot of an Aerobatic Aircraft Wearing ISECS

1.4 Project plan

1.4.1 This project commenced in April, 2001 and in order to achieve its objectives was sub-divided into a number of stages which are described in this the final report:

- Stage 1: Scoping of the project – this enabled identification of the issues surrounding the early identification of dyslexia from a theoretical and educational viewpoint. It also described technological systems that might have provided solutions from an eye tracking perspective.
- Stage 2: User Requirement Capture – During this phase of the project, the team identified the key user requirements from the perspectives of all potential users and those groups that were focused on understanding and supporting dyslexics. This involved a series of capture exercises ranging from group to individual discussions. In parallel, the QinetiQ eye tracking system, ISECS was used at the Learning Difficulties Clinic and a Hampshire LEA Primary school in order to

evaluate its appropriateness and the requirement for design modifications. The data obtained illustrated the potential of this project should it progress to a controlled research phase.

- Stage 3: System Design – In the penultimate phase of the project, a potential technological solution was designed, based on the user and system requirements developed in the earlier stages. This has identified the requirement to both modify existing systems and produce innovative solutions.
- Stage 4: Final Report – production of this final report and a presentation to all those stakeholders from the educational, policy and support group community.

1.4.2 Hence, the first task of the project enabled identifying the capabilities of the ISB3 project team and scoping dyslexia research. This enabled identification of the issues surrounding the early identification of dyslexia from a theoretical and educational viewpoint.

2 Scoping Study

2.1 The Problem

2.1.1 Dyslexia is difficult to diagnose and particularly so at an early age. There is currently no objective test for early detection (pre-readers) providing clear evidence of dyslexia, although in recent times, both computerised and behavioural tests have been introduced to identify those young children (4-5 years old) at risk. Early indicators include: developmental delays in speech and language; children finding it hard to co-ordinate fine (e.g. jigsaws) or gross (bike riding) motor actions; learn and memorise simple sequential tasks (strings of beads, order of common activities such as dressing oneself); and to remain concentrated and undistracted (Singleton, 2000).

2.1.2 Commonly, it is only when a young child fails to progress in reading and writing, as they move through the first years of school, that concerns are raised. The early indicators of dyslexia are likely to be confounded by the range of children's abilities and ages at baseline assessment and the psychological issues in settling in to school. These continue to cloud the identification of: slow spoken and/or written language, poor concentration, and difficulty in following instructions, and a tendency to be forgetful of words. It can therefore be a considerable period of time before these indicators are sufficiently clear to identify a dyslexic child. There are thought to be a number of language and non-language indicators that carers and teachers can use to identify possible risk. The British Dyslexia Association has summarised these. Examples of persisting factors are:

- obvious 'good' and 'bad' days, for no apparent reason;
- confusion between directional words, e.g. up/down, in/out;
- difficulty with sequence, e.g. initially coloured bead sequence, later with days of the week or numbers;
- a family history of dyslexia/reading difficulties.

2.1.3 As many as 10% of all children, irrespective of social class, have unexpected difficulty learning to read and spell properly despite having at least normal intelligence. Nowadays this is usually known by the neurological description, 'developmental dyslexia', because it is now accepted that it has a genetic/neurological, rather than a 'purely psychological' basis

2.1.4 It is important to highlight how dyslexia is associated with other medical and psychological difficulties. These include early speech and language problems, typical childhood illnesses (e.g. eczema, glue ear), dyspraxia, Attentional Deficit Disorder (ADD), social and emotional factors, poor time awareness, etc (Singleton, 2000).

2.2 Educational Perspective

2.2.1 In January, 2001, the DfES released statistics on SEN in English schools⁴ that:

- an estimated 260, 500 pupils had SEN statements;
- an estimated 1, 554, 100 had SEN without statements;
- in primary schools, 1.7% of the school population have SEN statements and 21% of the school population have SEN without statements.

⁴ Source DfES website SEN in schools in England – January, 2001 provisional estimates
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2.2.2 In order to identify those children at risk, a number of Local Education Authorities (LEAs) have introduced an early risk assessment for children in their first year at school. This risk assessment process helps teachers and SENCOs (Special Educational Needs co-ordinators) to both confirm initial suspicions and identify those children at risk of dyslexia.

2.3 The Importance of Early Intervention

2.3.1 The Dyslexia Institute considers that if dyslexia is identified during Key Stage 1 a great deal of support can be given in the normal classroom. However if diagnosis is delayed until Key Stage 2 the child is likely to need to be withdrawn from the classroom for specialist teaching for at least 1-3 hours per week. The most severe cases will need to go to a specialist school. Yet “when diagnosis of dyslexia is made in the first two years at school then 82% can be brought to the chronological age standard. If diagnosis occurs later towards the end of primary education the success rate falls to 10-15%” (Strag, 1972). Early intervention is the key as the effectiveness of intervention declines over the years at school (Thomson 1984). Studies in the USA suggests that the longer children with learning difficulties are left undiagnosed the more severe the impact of those difficulties⁵.

2.3.2 Dyslexia is difficult to diagnose and particularly so at an early age. As a respected researcher in the area commented “Unfortunately, there are no generally accepted objective procedures for identifying such children at an early age....Education authorities require more objective evidence in order to make special provision. There is therefore a need for formal assessment procedures that are not inordinately costly or time consuming but which are sufficiently reliable to justify taking action”.⁶

2.3.3 Early identification will lead to intervention focused on the ‘at risk’ child leading to the development of targeted education plans. Once correctly diagnosed, strategies for improvement and coping with their areas of difficulty can be developed. Recently tests have become available⁷ that enable the risk of a child developing dyslexia to be quantified. Sheffield University has developed the Dyslexia Early Screening Test (DEST) (Fawcett and Nicolson Lee, 1986) and has just released a version for younger children (October, 2001). These reflect the priority for early intervention to identify children with dyslexia before they fail to learn to read, that is, at six years or earlier.

2.3.4 DEST was designed to provide the first stage in a three stage screening, assessment and support system. It is a 30-minute screening test normed on over 1000 children in the UK, comprising 10 short subtests spanning a wide range of skills known to be positive indicators of dyslexia. The DEST includes tests of speed, motor skill, phonological skill, balance, auditory temporal processing, shape copying, and pre-reading knowledge. If a similar approach could be adopted with even younger children, so those children are ready to learn when they reach school, it is possible that failure could be largely eradicated. The Pre-school Screening test (PREST), was developed for children aged 3.6-4.5 (Fawcett, Nicolson and Lee, 2001). At this stage, it is appropriate simply to identify those children who might be ‘at risk’ for early difficulties of any type. These tests do not indicate whether a child has a visual impairment related

⁵ By early intervention, society benefits as well as the child. ERIC Digest 455, Smith, Barbara J.1988

⁶ Singleton, C (2000) Guest Article, Understanding Dyslexia: Introductory Notes, <http://www.devdis.com/guestart-jun.hmt1>

⁷ Fawcett, A.J., Singleton, C.H. and Peer, L. (1999) Advances in early years screening for dyslexia in the United Kingdom. *Annals of Dyslexia* 48: 57-88.

to dyslexia nor do they offer visual evidence of such impairment. However, they do provide a risk score that can screen the child's potential to develop reading difficulties.

2.4 Overview of Early Years in Primary Education

2.4.1 The scoping exercise highlighted several key points:

- the prevalence of SEN and specific reading difficulties in schools is considerable especially when figures do not include those pre-school and school children who have unrecognised difficulties;
- the range of possible language and non-language indicators for dyslexia are not a definitive list and require that each teacher treats a child individually; most are not measurable objectively;
- each child has a legal basis for their SEN to be both identified and addressed. The process to achieve this has external assessment as part of the legalised process;
- the process of making provision for children with SEN culminating in a SEN statement requires external evaluations. It may be that an output of this project could be concepts for the provision of additional objective evidence for an SEN statement process;
- LEAs are starting to assess 4-5 year old children for risk of developing specific learning difficulties;
- dyslexia is linked in ways unknown to a number of other difficulties and it is important that these relationships are acknowledged in cognitive profiles;
- late and absence of identification has a severe impact on the educational and social development of a child.

2.4.2 Hence, there has been a growing need for the development of early tests of dyslexia, identifying risk, making the first steps towards this goal. However, it is possible that there are novel objective methods that could help identify underlying neurobiological and behavioural risks. It may be that a novel solution as proposed here could be linked to existing tests, procedures and ultimately remediation.

3 Theoretical Overview

3.1 Review

- 3.1.1 A distinction that can easily be made is between *acquired* dyslexia and *developmental* dyslexia. The former is encountered in adults who, having successfully learned to read as children, suffer an area of brain damage (usually through stroke), with the result that their reading becomes impaired. Children, who fail to develop reading skills commensurate with their age and general mental ability, exhibit the developmental form of the condition. One subgroup suffers from what is termed phonological dyslexia; sufferers appear to have lost the ability to derive the sounds of words from their spellings. They recognise words reasonably well, including irregular words, such as **choir**. However, they would be quite unable to pronounce a nonword, such as **brane**.
- 3.1.2 It is certainly the case that many studies have implicated phonological problems in children with reading difficulties. For example in one study⁸, children from 'at risk' families were monitored over a period of years, and compared with low-risk children. As the children grew older they all passed through the usual developmental stages of first learning letter names, then going on to know the sounds associated with the letters. This advancement took place, on average, two years later in the high-risk group. As was explained in the context of acquired dyslexia, if there is a phonological problem the sufferer will be unable to read nonwords. An electroencephalographic (EEG) examination of dyslexic children and normal readers showed a marked difference in the EEG signals of the two groups, with the dyslexics showing no evidence of processing the nonwords.
- 3.1.3 A sound-based route for reading may be presumed to make use of speech analysis pathways, and it has been shown that dyslexics find difficulty in a number of language related areas. For example, dyslexic children may experience difficulty in distinguishing between the spoken sounds 'ba' and 'da'. Many even exhibit impairment in producing their own speech, a problem that can be revealed by asking them to name pictures as rapidly as possible. Perhaps very significantly, it has been shown that those Chinese children who experience reading-specific difficulties also perform poorly in tests of phonological awareness. This is impressive, in a language where the orthography is presumed not to make use of the sound-based route. In spite of the large body of evidence implicating phonological problems, apparently anomalous findings sometimes emerge. For example, Bosman, van Leerdam and de Gelder⁹ tested the speed of naming the first letters of words. Children with normal reading ability can respond more quickly to a word like **over** than a word such as **otter**, because the *sound* of 'O' (the letter name) is present in the former. Interestingly, that pattern of results was also found in dyslexics, who had been presumed to be rather unaware of the sounds of the words.
- 3.1.4 "There is unanimous agreement that problems with phonology are associated with dyslexia, however, it is becoming clear that phonology is not the only problem. Phonology is a skill underlying the analysis of both spoken and written language; breaking down words into their parts, or segmenting them, so first knowing that 'cat' is made up of the onset and rime c-at, and then recognising the individual sounds (phonemes) are c-a-t. Phonological awareness is also used in hearing a sound (a phoneme) and translating it into a letter that represents it (a grapheme). These skills

⁸ Pennington, B.F. and Lefly, D.L. (2001). Early reading development in children at family risk for dyslexia. *Child Development* 72 816-833

⁹ Bosman, A.M.T., van Leerdam, M. and de Gelder, B. (2000). The |O| in OVER is different from the |O| in OTTER: Phonological effects in children with and without dyslexia. *Developmental Psychology* 36 817-825.

need to develop around the age of 5, if young children are to learn to read successfully. Otherwise, they are limited to reading words they recognise as a whole (orthography) and are limited in their ability to learn new words. There is solid evidence dating from the work of Bradley and Bryant, 1983, that rhyming is impaired in children with dyslexia. In a research programme spanning many years, Snowling and colleagues have investigated phonological deficits over the life span, in particular the ability to read nonsense words, which depend on both the ability to segment and grapheme/phoneme translation. There is a clear brain basis for phonological difficulties, based on a difference in areas involved in language (the sylvian fissure and the planum temporale). Despite all the evidence, Frith concludes (1997, p11) "the precise nature of the phonological deficit remains tantalisingly elusive." (Fawcett, 2002)¹⁰

- 3.1.5 With a broader emphasis, the sensory theories account for both visual and phonological difficulties and one particular theory is that of Prof Stein of the Oxford Dyslexia Unit¹¹ which has formed the theoretical basis of this research. Prof Stein outlines his theory and findings in the next section.

3.2 Physiological Perspective on Potential Root Causes of Dyslexia

- 3.2.1 The vast majority of children teach themselves to speak without any difficulty. Yet a few years later when they come to learn to read they need to be taught how to do it; they seldom pick it up by themselves. Why is reading so much more difficult than speaking?

- 3.2.2 150 years ago the majority of the population had little use for reading; it was confined to a small elite, and only in the last 50 years has it become essential for employment. So, evolutionarily speaking, it is improbable that reading ability provided any significant selective advantage. Hence no part of the brain has specifically evolved to achieve it; in other words it is very unlikely that there is a specific reading gene; and much more likely that the genetic basis of reading ability is related to more basic perceptual abilities that evolved earlier of which reading has taken advantage.

- 3.2.3 Without any particular teaching, by the time a child is seven years old s/he has already amassed a vocabulary of about 3,500 words, mainly of one or two syllables. It was only a few thousand years ago that it was realised that these syllables could be represented on paper by a far smaller number of symbols if they were broken down to the smallest acoustic units that are distinguishable (40 phonemes in English) which can then be represented by an even smaller number of letters or groups of letters. Reading is difficult therefore, because a child has to learn in just 2-3 years to do what humanity took tens of thousands of years to develop. S/he has to learn to parse each word into its separate letters visually, then to translate these into the sounds they stand for.

- 3.2.4 Thus accurate visual analysis of the order of letters in words is crucial to successful reading. But this process is not as easy as it sounds, because the eyes are on the move all the time. They flick from letter to letter across the page. Hence not only has the form of each letter to be analysed, but also the direction in which the eye was pointing at the time has to be registered in order to know in what order the letters were viewed. Add to this that the two eyes may be pointing in different directions because they are not perfectly yoked together and one can see that visual analysis of the spelling of words, apparently simple, is actually a highly complex process. We¹² have been

¹⁰ http://www.dfes.gov.uk/sen/documents/Recent_research_development_.htm

¹¹ <http://www.cogneuro.ox.ac.uk/dyslexia/>

¹² Prof John Stein and colleagues

interested for many years in understanding how these visual problems can contribute to an understanding of the potential physiological mechanisms of dyslexia¹³.

- 3.2.5 The control of the movements of the eyes and the registration of their position is now known to depend on how well a subsystem of the visual system, known as the magnocellular system, develops. The visual and auditory processes that are required for reading depend upon the ability of the nervous system to track accurately changes in light and sound (transients); this function is carried out in the brain by a particular kind of large (magnocellular) nerve cell. The sensitivity of this system can be measured fairly easily in children and it is now known to be mildly impaired in many poor readers such as developmental dyslexics. It is contended that this impairment correlates with the weakness of their visual magnocellular system¹⁴. Probably they inherit a genetic vulnerability of their magnocells to attack by maternal antibodies in utero and/or to the effects of adverse nutrition. In particular dietary deficiency of flexible polyunsaturated fatty acids can contribute to their damage. These are found, for example, in fish oils and their flexibility confers the rapid responses that magnocellular neurones need to track sensory transients.
- 3.2.6 Therefore many dyslexics are found to have reduced performance of their eye control system, especially when reading. Thus the stability of their eyes when fixating stationary targets is less than that of good readers; their ability to smoothly track targets moving slowly horizontally is poor and this is even worse when dyslexics are asked to track targets moving in depth when vergence movements are needed to bring the two eyes together as the target moves nearer to the nose. Such vergence adjustments are made frequently when reading small print positioned only about 20 cms away. These impairments of eye control are caused by the impaired development of the visual magnocellular system that is found in dyslexics.
- 3.2.7 These deficits translate directly into impaired stability of dyslexic's visual perceptions when reading. Such children often complain that letters appear to blur and to move around the page when they are trying to read. Thus they often suffer unpleasant visual discomfort, glare and shimmering of the print. Quite often however, they are not aware that letter blurring and motion is not how most people experience print; so that they don't volunteer these complaints, but admit to them if asked. Their visual discomfort puts them off reading, and they try to avoid it whenever possible. Hence their initial difficulties get compounded and they enter a vicious circle of difficult and painful reading, unwillingness to practice, hence falling further and further behind.
- 3.2.8 Since these children know that they are as intelligent as other children in other ways and cannot understand why reading is so unpleasant for them and not for their friends, they lose self-confidence. They get taunted and teased, and this leads to depression and despair, and very often into a downward spiral of frustration, rebellious behaviour, violence and delinquency. Over half of prisoners in gaol are thought to be dyslexic. This is doubly worrying: not only can most dyslexic problems be alleviated if they are recognised early enough, but also there is now quite a lot of evidence that the deficits that give rise to reading problems may actually be associated with unusual strengths in other fields such as the Arts, Engineering, Computing and Commerce. Perhaps many of the criminals now residing in gaol or causing problems in the community could have

¹³ Stein, J., Talcott, J., & Witton, C. The sensorimotor basis of developmental dyslexia. A. Fawcett (Ed.), *Dyslexia: Theory and Good Practice*. pp. 65-88., London: Whurr British Dyslexia Association.

¹⁴ Stein, J.F. & Talcott, J.B. (1999). Impaired neuronal timing in developmental dyslexia-The magnocellular hypothesis. *Dyslexia*, **5**, 59 - 78.

- been making useful contributions to Society if their dyslexia had been diagnosed and treated properly.
- 3.2.9 We now know that there are many ways of helping children with ocular motor control problems. In children under the age of 9 with binocular instability, blanking one eye when reading helps them to clear up the confusion that they suffer when the images provided by the two eyes superimpose themselves; this also helps them to gain stable eye control. But this treatment does not usually help in older children whose neural pathways have become less plastic. In other children, yellow filters can bolster the performance of the visual magnocellular pathways relative to other systems, so that their visual problems are often helped by viewing the print through yellow overlays or wearing yellow tinted sunglasses. In yet others, eye exercises that train the eyes to fixate more steadily on the letters and words can often help the child dramatically.
- 3.2.10 Dyslexics do not just have problems with reading. Most are also bad at putting things in the right sequence, such as the days of the week and months of the year, and they are often very clumsy because of poor motor co-ordination. Many have trouble learning to ride a bicycle; their writing tends to be appalling and they often have problems telling left from right. Reading problems tend to run in families; i.e. they have a genetic basis. Among others, genes near the Major Histocompatibility immune regulation Complex (MHC) on the short arm of Chromosome 6 are almost certainly implicated. Thus dyslexia has a clear neurological and genetic basis. Nevertheless some people still regard it as a middle class fraud designed to gain special treatment for their stupid children, rather than as a real neurological condition, and these ill informed prejudices are difficult to dispel.
- 3.2.11 Always however, it is first necessary to identify the children who have these ocular motor problems. In almost all studies so far it has only been possible to study older children using complicated apparatus in a laboratory setting. What is really needed is equipment that will allow us to estimate the quality of younger children's eye control in a normal pre-school setting, so that one can identify children with visuomotor problems at the time when we have most chance of helping them.
- 3.2.12 This is the background to our interest in developing techniques for identifying children's eye movement control problems as early as possible - before they begin to fail at reading. The evidence is now strong that many children with reading difficulties have weak visual magnocellular function that compromises their binocular eye control, and that this causes visual reading problems. But so far there has not been the means of identifying the children who have such poor eye control at a young enough age when educators have the best chance of helping them.
- 3.2.13 What was needed was an eye movement recording system that we could use with 4-5 year old children with the minimum of calibration, in order to assess their ocularmotor performance in the short attention time span that children have at that age. One of the main problems with working with young children is that it is not easy or desirable to restrain head movements, so that the ideal system should measure gaze (head plus eye movements) rather than just movements of the eye in the head. The gaze tracking technology developed by QinetiQ for use in the extremely hostile environment of the cockpit of a jet fighter does exactly this. Hence it seemed just what was required, if it could be adapted for use with the much smaller faces of children compared with those of pilots.

- 3.2.14 Knowledge of how dyslexic brains are different from good readers is enabling researchers to design treatments to help them to overcome their problems. The brain is very malleable, particularly in young children, and the right treatment applied at the right time can have dramatic results. Oxford University's tests of visual and auditory transient sensitivity are very simple and can be turned into games that small children can do before they even begin to learn to read. Staff can therefore assess children's strengths and weaknesses, hence predict which children are likely to have problems with either phonics or orthography or both. This will enable the team to design training programmes targeted at the weaknesses of each individual child.
- 3.2.15 This confidence is not just wild optimism. We have shown that the simple treatment of patching the left eye when reading can often help stabilise the eyes of 7 - 10 year old children with weak visual magnocellular function, and hence unstable eye control¹⁵. Hence improving their orthographic skills and doubling their rate of reading progress. Likewise the team have found that wearing yellow or blue filters can help many children with visual problems to control their eyes better, and help their reading. Furthermore there is encouraging evidence that properly targeted auditory training can improve children's sensitivity to the acoustic transients that distinguish letter sounds, and thus help them to improve their phonological skills. In addition recently it has been shown that supplementing dyslexics' diet with extra polyunsaturated fatty acids can improve their magnocellular function, hence help them to learn to read better. The key, then, to enabling dyslexics to minimise the impact of their condition on their lives is both early detection to provide coping strategies and appropriate individual education
- 3.2.16 We have found that assessing people's magnocellular sensitivity by measuring how well they can hear frequency changes (warbling tones) and how sensitive they are to moving visual targets tells us a great deal about how well they can read. In fact people's performance in these simple sensory tasks accounts for most of their differences in reading ability. This is true of all readers, good or bad, children or adults. It really is very remarkable that sensitivity of the sensory systems to these very simple, low level, stimuli can explain how well the much higher level cognitive skills required for reading develop, independently of general intelligence, teaching quality, cultural opportunity, etc.
- 3.2.17 In summary, it seems likely that reading and spelling problems are ultimately caused by slight weaknesses in visual and auditory sensory processing of temporal transients, because the development of magnocellular neurones in the brain is abnormal in dyslexics. Conversely these brain cells are well developed in good readers.

3.3 Way Forward

- 3.3.1 Prof. Stein and his co-workers have carried out promising eye-tracking studies, which reveal a lack of ocular control in dyslexics, compared with normal readers. The optical 'wandering' was attributed to impairment of the magnocellular signal, and hence could be described as a timing problem. This laboratory-based research used children aged approximately eleven years. With such a population there is always the possibility that the poor ocular control is a result of poor training. The argument is that learning to read fosters accurate eye-control, so that normal controls, who have been confronted with text for five years or more, will perform well on measures of eye stability. If the dyslexics find reading difficult, perhaps for a non-visual reason, then they will probably have less exposure to printed material, and fail to develop effective ocular control. Thus, it is still

¹⁵ Stein JF, Fowler MS & Richardson A (2000). Monocular occlusion can improve binocular control and reading in dyslexics. *Brain*, 123, 164 - 70.

not entirely clear that the dyslexics' problems are primarily visual, or that they are attributable to a deficit in the transient signalling circuits.

- 3.3.2 There is also significant controversy in the potential route causes of dyslexia¹⁶ and many diverse theories. In order to ensure that a future project represents an inclusive approach to dyslexia, in particular regarding alternate theories¹⁷, it is recommended that an additional partner be sought with a different emphasis and skills. In particular, by combining screening tests, such as the DEST with the eye movement tests, it is intended to draw up a relatively complete profile of skills, which can subsequently inform the research of a broader profile of each child's performance and assist in the development of remediation.

¹⁶ Stein, J., Talcott, J., & Walsh, V. (2000). Controversy about the visual magnocellular deficit in developmental dyslexics. *Trends in Cognitive Sciences*, 4, 209-211.

¹⁷ Fawcett, A.J. and Nicolson, R.I. (1999) Performance of dyslexic children on cerebellar and cognitive tests. *Journal of Motor Behaviour* 31, 1: 68-78

4 User Requirements

4.1 General

4.1.1 The task of the next phase of the project was to determine the formal requirements for using an eye tracker in a typical school environment. These requirements would then form the basis for the design of a detection aid for dyslexia associated with a visual deficit (eye-wobble). Requirements capture is a formal discipline, within systems engineering, that ensures products are developed in line with requirements, ensuring that they meet customer needs and are testable and verifiable to known standards.

4.2 Requirements Documentation

4.2.1 User Requirement Documents (URD)

4.2.1.1 URDs describe the objectives, goals and outcomes of the need; conventionally this is what the final product is **accepted** against. The following actions are carried out in order to generate user requirements:

- identify the need for the system;
- identify users and user types;
- capture the User Requirements;
- structure, rationalise and refine the User Requirements.

4.3 Current Assessment Environment

4.3.1 Assessment Principles

4.3.1.1 One of the fundamental weaknesses in the current method of identifying a child with dyslexia is that formal identification usually starts once a child has failed to prosper at reading and/or writing. This inevitably means that assessment processes tend to be focussed towards older children and precious opportunities for earlier intervention may be lost. It can also add to the difficulties faced by the child as the early sense of failure frequently results in behavioural problems adding to the complexity of their special educational needs and the support required to help them

4.3.1.2 It is important to recognise that technology can play a part in assisting identification of specific learning difficulties such as dyslexia at an earlier stage, but only in conjunction with other diagnostic tools. Whilst it may assist as a top-level indicator and possibly characterise certain physiological causes in some way, it cannot take the place of a detailed assessment. The assessor is able to develop a full cognitive profile of the child giving due consideration to factors such as, hereditary aspects, absence from school through illness, emotional or social problems and related difficulties, e.g. the possibility of vision or hearing difficulties.

¹⁸ Principles of Assessment – Dyslexia Review Magazine, Janet Townend Head of Training, Dyslexia Institute

4.4 User Requirements

4.4.1 Structure and Scenarios

4.4.1.1 The raw requirements were transformed into a clear top-level set for review as portrayed in Section 4.5. Scenarios describing the actions or behaviour of the system throughout its life cycle still need to be identified and agreed with project sponsors. Only two main scenarios seem to have come to the fore:

- an automatic or semi-automatic, SENCO-utilised system operated in a classroom environment that provides diagnosis and reports as required in short timescales;
- a system requiring specialist knowledge and an environment similar to that operated by ophthalmic consultants.

4.4.1.2 These are two extremes that are useful possibly to bound our thinking in conjunction with the selected relevant system, reproduced below.

4.4.1.3 Significantly, in the delivery of an appropriate system meeting these user needs, it will be necessary to consider: the design, development, delivery, maintenance and ongoing support of such a system that will be able to assist in the prediction, detection, identification and characterisation of any visual aspects of SLD that might benefit from the early application of remedial action.

4.5 Key User Requirements

Serial	Requirement	Details	Key Users
1	Technically achievable	The proposed solution should be acceptable in terms of technical development risk, taking into account mitigation and technical alternatives. It should also be acceptable from a manufacturing standpoint.	Sponsors, funding agencies, researchers, system developers, manufacturers.
2	Diagnostically beneficial	The proposed system should be sufficiently accurate/measure sufficient parameters in order to be beneficial to the process of diagnosing or characterising dyslexia and should not, by its design, preclude in assisting in the diagnosis of other conditions by observing visual behaviours.	Children at risk, of dyslexia or other conditions, parents, SENCOs, teachers, researchers, system developers, sponsors, manufacturers.
3	Provide confidence	All users must have confidence in its use and subsequent results. This requirement encompasses issues such as initial acceptance testing, repeatability, speed and ease of calibration routines and visibility of the current state of accuracy and calibration through the use of some indicator or other method.	Children at risk, System operators, SENCOs, teachers, parents, sponsors, auditors, maintainers.

Unclassified/Unlimited

Serial	Requirement	Details	Key Users
4	Accept/Provide Information	Any proposed system must be capable of storing, accepting, transferring comparing and retrieving data and information relating to: user instruction, subject details, particular test details and parameters.	Children at risk, System operators, SENCOS, teachers, parents, sponsors, auditors, maintainers
5	Usable	Any proposed system must be child-friendly and comfortable in terms of ergonomics with factors such as head size, inter-ocular distances, coping with spectacles. The system must also be as appealing as possible and not be frightening. Usability extends to system operators with the provision of a good intuitive interface that maximises ease of use and minimises test time and training requirements.	Users in terms of subjects (children) and system operators (SENCOS)
6	Safe	The system must be inherently safe and not cause harm. This requirement covers the full range of safety aspects from the relatively simple mechanical aspects and electrical safety concerns through to the use of intense infrared illuminators in ISECS type designs. Depending on the proposed solution, consideration must also be given to mass. Compliance must be achieved.	All users, regulatory and compliance bodies
7	Durable	The proposed system must be robust and be able to cope with the intended environment. It must achieve required reliability levels.	All users, system maintainers
8	Maintainable	The proposed system must be modular in design and construction with easily diagnosable fault conditions that can be quickly repaired.	All users, system maintainers
9	Integrated	The proposed system, by its nature, should complement and not conflict with the current system. The design should not preclude its use in remediation by the use of filters, for example, nor collection of data that might help validate visual theories.	All users
10	Financial viability	The proposed system must be financially viable as demonstrated by a positive cost benefit analysis or attractive NPV.	Sponsors, funding agencies.

Table 4-1: Key User Requirements Outline Design of a Suitable Eye Tracker

5 Outline Design of a Suitable Eye Tracker

5.1 Early Prototyping

5.1.1 In parallel with requirements capture, a major task was to look into the appropriateness of QinetiQ technology for this project. Trials were carried out at the Dyslexia Research Trust Learning Difficulties Clinic and adaptations made. This then led to a test of the child-sized system at a Hampshire LEA Primary School with children at risk, not at risk and those identified with dyslexia.

5.2 Lessons Learned from the Key User Requirements

5.2.1 Size

5.2.1.1 The first lesson was that the industrial safety spectacles on which the original ISECS module was mounted were too large. The module was therefore redesigned so that it could be mounted on a variety of child-sized wire-framed spectacles donated by a local optician.



Figure 5-1: The ISECS Module Adapted for Mounting on Children's Wire Frame Spectacles

5.2.1.2 The result, shown in Figure 5-1, added a weight of about 65g to the 23g frames. The smallest glasses were intended for children aged from about five to eight, the medium size suited those aged eight to eleven years and the large size was intended to bridge from eleven to adult. This equipment was used to obtain recordings from six children attending the Oxford clinic and from nine attending the Harrison Road primary school in Fareham, Hampshire.

5.2.2 Acceptability

5.2.2.1 The tests were revealing. Older children accepted the spectacles readily, but some, particularly the younger (5 year old) children who had not previously worn spectacles were initially reluctant and had to be cajoled gently before they would put them on. Once on, all seemed happy to continue to wear the spectacles, despite their weight, and for all of the children the glasses made a stable platform for recording eye and scene images during the short, approximately ten minute, sessions. A reduction of the total weight would be worthwhile, mainly to reduce the chance of discomfort for young children.

5.2.3 Robustness and Setting Up

5.2.3.1 Most children sat fairly still and held a steady head posture, but some wriggled, looked around and periodically touched the spectacles. A light elastic headband was used at the school, and this practically eliminated movement of the spectacles relative to the children's heads, so slippage is unlikely to be problematical. It would be wise to arrange for the optics to resist smearing and misalignment though inadvertent finger contact. It was also of note that although the module could be transferred to a different spectacle frame and adjusted in position in about five minutes, the process was fiddly. To be routinely practical the arrangement must be considerably easier to manage.

5.2.4 Scene Camera

5.2.4.1 Three scene camera lenses giving different fields of view were tested. The widest field of view, approximately 60° diagonal, was needed to cover the eye excursions over the locations in which the test material appeared in the scene image given the unconstrained head postures adopted by the children. Two limitations were apparent. The first was the poor rendition of the detail in the reading material, which was due mainly to the dilution of the camera spatial resolution in covering the wide field of view. Secondly, although the scene camera could be focussed on the test material at the start of the session, the depth of focus barely accommodated the children's natural head movements towards and away from the test material.

5.2.4.2 It would be advantageous to improve the sensor resolution, reduce the field of view and increase the depth of field. To compensate for a narrower camera field, it seems reasonable to induce the children to point their head towards the test material by artificially limiting their field of view. However, this idea has not been tested.

5.2.5 Eye Camera

5.2.5.1 There were several deficiencies in the eye sensor. In particular, the range of focus adjustment did not accommodate the comparative closeness of many of the children's eyes. In any future design a broader range of focus adjustment, and perhaps an extended depth of field, are essential.

5.2.5.2 It would be better to extend the focal length of the eye camera lens and reduce the captured area. This reduced area would still cover the salient features and their movement with eye rotation, providing the camera could be adjusted to centralise the features when the child looks straight ahead. Any design that provides a reduced captured area must therefore include a facility for accurate positioning of the eye camera axis relative to the individual eye, both vertically and horizontally.

5.2.6 Calibration

5.2.6.1 Calibration is the process for determining the relationship between the differential position of the features in the eye image and the eye pointing direction within the scene camera field. This was done retrospectively from the interleaved recordings by careful choice of instances when the fixation direction could be presumed. However, calibration would have been simplified greatly had a more rigorous and consistent procedure been organised for instructing and guiding the children to fixate steadily on a marker that could be positioned accurately over the scene camera field at the same distance as the reading material.

5.2.6.2 The offset between the scene camera and the eye was also a source of inaccuracy. A substantial reduction in the offset is needed if children are to be allowed natural head movement.

5.2.7 Usefulness

5.2.7.1 Those recordings that were amenable to automatic analysis showed clearly the variety of ways that the children fixated on words, pictures and moving points of light. This, largely qualitative, insight into their behaviour was itself valuable. It was of note that the system could discriminate eye movements of less than one degree but no fixation wobbles of this magnitude were apparent with the children who participated in the tests.

6 The Outline Details of a Proposed Design

6.1 Overview

6.1.1 The scheme proposed to meet the requirements and incorporate the lessons learned from experimentation with the adapted ISECS/PORT module extends the existing arrangement by providing a pair of eye and scene cameras, one for each eye, and by introducing an auxiliary sensor capable of greater resolution, accuracy and frequency of eye measurements. Facilities that enable significantly easier setting up and operation are also incorporated.

6.2 Possible Elaboration

6.2.1 The proposed configuration of equipment could be elaborated to gain several benefits.

6.2.2 First, it would be possible to use a binocular head-mounted display to relay the images captured by the two scene cameras of the spectacle-mounted sensor unit. If the display fields of view and alignment matched the sensor geometry, an observing adult would receive stereoscopically the child's egocentric view of the test material and see the child's pattern of eye movements over the features in the material. The child's vergence eye movements when watching an object move in depth would also be clearly apparent. It would not be fanciful to suggest that this method of presentation could give the adult an enhanced and immediate appreciation that would be almost an insight into the mind of the child.

6.2.3 Secondly, it would be possible to use the computer monitor as the screen for displaying test material. The material could take the form of static images to be read, named or searched, but dynamic imagery would also be possible, for instance to allow control over the time for which an image was presented, or to generate moving targets. Computer control over the imagery could also be combined with the eye movement measurement to alter the imagery dynamically in response to eye behaviour.

6.3 Crucial Issues

6.3.1 Although the proposed equipment configuration should meet the main requirements, the practical implementation depends on the satisfactory optimisation of many details.

6.3.2 The two major areas are the design of the spectacle-mounted sensor module and the computer software. The former would have to be designed to collect eye and scene images that had better resolution than the present ISECS, and the unit must be significantly lighter, more robust and easier to set up. The module must fit any spectacles likely to be used by children, and the images of the eyes must not be affected adversely by reflections from the surfaces of the corrective lenses in the spectacles.

6.3.3 It is intended that a follow-on project funded under ISB4 will enable the development of an innovative system that enables binocular tracking and analysis of the eye behaviour of young children in a classroom environment.

7 Conclusions

7.1 Review

7.1.1 The original objectives of the project as outlined in the Project Implementation Plan have not only been successfully met but the final output has surpassed the original outcomes and has indicated wider benefits to be obtained from ISB4 than originally envisaged:

- we have designed a novel system specification that meets the criteria;
- moreover, we have built and tested a prototype system based on an adaptation and miniaturisation of the military eye tracking technology for young children;
- finally the system has been demonstrated in a school classroom with infants at risk of developing dyslexia using screening techniques.

7.1.2 These additional early tests of the prototype both in the school setting and with dyslexic children at the Learning Disabilities Clinic provided proof that the system was able to accurately measure eye point of gaze and show where a child was looking on the material he was reading. This is a very pleasing result and reduces technical risk for the future research. It also allowed the team to identify the shortcomings of the prototype and propose modifications. Users have been consulted about the prototype and their needs and these have been fed into a user requirement report that has received strong support from early users of the equipment.

7.1.3 Additionally, the teachers, SENCOs and those involved in dyslexia detection have commented on the power of seeing a child's visual reading strategy for the first time in a real setting. This allowed the educator not only to look through the child's eye but also added unexpected benefits, e.g. understanding which letters or words caused difficulty or whether the child's eye movement was controlled. In parallel, it has been recognised that such information may be relevant to a range of disabilities. One academic researcher has also identified the equipment as a possible tool to help train teachers to teach children to read.

7.1.4 The ISB project has identified that there is a stronger incidence of phonological dyslexics than visually impaired dyslexics. If this is the case, it is likely that an eye movement system would detect a third of the dyslexic population. However, the impact of such early detection on school success and the child's welfare is significant. Moreover, if an underlying system, e.g. magnocellular system, is at fault, potentially any detection method that identifies this problem may indicate problems in the auditory domain. However, it is clear that an early detection system for auditory processing problems would be very welcome.

7.2 ISB outcomes

7.2.1 One of the three priorities for ISB Round 3 was to support projects with a citizen focus which built service delivery around the needs of particular user groups or life events. This priority was reflected in a series of project objectives that are assessed in Table 7-1 below.

Original Objectives	Outcome
The overall objective is the utilisation of defence research and development to benefit the learning difficulties and special needs community.	Clear exploitation of MoD funded hardware leading to novel, child sized eye movement system.
Foster closer working relationships with all stakeholders	Strong partnership leading to foundation of ISB4 bid and identifying new partners leading to inclusive approach.
Confirm the scientific basis of the initial research	Delivered detailed report scoping the theory behind dyslexia ¹⁹ and providing academic and financial confirmation for the need of early identification and intervention.
Develop a detailed understanding of the technical requirements necessary to aid in the diagnosis of learning difficulties	Guidance of Prof Stein and early trial of prototype in Learning Difficulties Clinic led to technical requirements ⁴ .
Develop formal user requirements for a child friendly, ruggedised eye tracking system	Delivered report ²⁰ outlining user requirements captured through individual meetings with experts in schools, academia and industry.
Develop a <u>design specification</u> which will be the subject of further research and development	The QinetiQ technologists and the project team have successfully outlined a design to provide the basis for an objective test to aid in the detection of childhood dyslexia. This will allow accurate dual-eye tracking capability.
To offer advice on the <u>practicalities</u> of using such a device, e.g. who is best placed/qualified to administer the test, environment in which test carried out and issues to do with age of pupil subjects	Final report (in progress due Feb 02) pulls together the preceding strands of the project and will provide clear guidance on practicalities for ISB4. The final presentation to the user community will offer and receive advice.
	<ul style="list-style-type: none"> • Built a child-sized, innovative prototype • Tested this in the laboratory and classroom in terms of usability, reliability, ruggedness and accuracy • Identification and involvement of an 'Advisory Group' for benefit analysis

Table 7-1: ISB Objectives and Outcomes

¹⁹ Early Identification of Dyslexia: Report on a Scoping Study, QINETIQ/FST/CSS/CR011929/1.0, 2001

²⁰ Aid to the Early Detection of Dyslexia: User Requirements Report, QinetiQ/FST/CSS/CR0211929/1.0, 2001

8 Recommendations

8.1 Recommendations from the Scoping Study

8.1.1 The following recommendations were made:

- the project must address the requirements of the SEN Code of Practice to ensure that a new test helps support the steps towards early identification;
- it would be advantageous if a new test was compatible in timing, and potentially as a correlate, with the existing risk tests that are being used;
- the eye tracking system should be considered as a method of identifying other indicators of dyslexia and SEN;
- use of a complex system with young children requires that the technology be child friendly, robust, safe and comfortable. Further developments need to encapsulate these needs;
- there is a range of theoretical explanations of dyslexia. It is recommended that the developed system is capable of collecting data to help validate visual theories. These include eye control, learning and magnocellular theories;
- phonological dyslexics are more predominant. It is recommended that where possible the visual detection system is linked to the results of auditory tests and may even be used with such tests;
- a longitudinal research study is advised to identify the validity of the output of this seedcorn project.

8.1.2 As Singleton (2000) comments there “are characteristic types of dyslexic children that could often be identified much earlier than is typically the case at present. Unfortunately, there are no generally accepted objective procedures for identifying such children at an early age..... Education authorities require more objective evidence in order to make special provision. *There is therefore a need for formal assessment procedures that are not inordinately costly or time consuming but which are sufficiently reliable to justify taking action.*”

8.2 Next steps: Outline Design

8.2.1 The recordings that were obtained with this new design have been outstandingly successful. In particular the ease of calibration has meant that the team has already been able to make good recordings in 4-5 year olds. These pilot results have clearly shown that the system works with small children, it can be used easily, and the recordings can be successfully analysed. However, the user requirements specified have identified shortcomings in the ISECS based design that need to be addressed in future research.

8.2.2 At present the spectacle-mounted system is still rather heavy for young children but in the future it could easily be miniaturised further to make it lighter. Furthermore at present one can only measure the movements of one eye, whereas many of a dyslexic’s problems are the result of their vergence deficiencies, and the team wish to assess these by calculating the degree of correlation between the movements of the two eyes. Hence future work is needed to duplicate the system for measurement of the movements of both eyes. Finally at present the computation of the moment to moment position of the eyes is slow and cannot be carried out on line. However modern dedicated processors are fast enough to carry out the necessary calculations.

8.2.3 Although the design of a satisfactorily integrated and lightweight module for mounting on spectacles and the development of the computer software present numerous detailed engineering challenges, the overall scheme is feasible.

8.3 Research Requirements

8.3.1 In order to realise these recommendations and to provide objective evaluation of the validity of early detection of visual reading difficulties with dyslexia, there is a need for controlled research trials. It is proposed that such a project would enable descriptions of young children's dyslexic profile, eye movement behaviour and validation of the 'eye wobble' theory through a series of stages. The research would be conducted in the school setting with the aim of ensuring that the system can be properly and objectively assessed in terms of:

- its value/impact as a means of early identification of dyslexia;
- user-friendliness (child users and adults who have to administer);
- its relationship to other early screening tests/means of early identification of dyslexia and how the system might contribute to wider early intervention strategies.

9 Acknowledgements

9.1 The team would like to acknowledge the invaluable contributions of Alison Thompson at the DfES, Pauline Bentote of Hampshire LEA, Harrison Primary School, the Learning Difficulties Laboratory, and children involved in this project. Without their contributions progress would have been limited.

Report documentation page

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10a. Abstract. (An abstract should aim to give an informative and concise summary of the report in up to 300 words).			
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