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Research Article

Vision Screening in Primary Education (A Cure for Dyslexia?)

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Abstract

This study found that up to 88% of the children at Hemyock Primary School had the predisposing signs to reading difficulties. This was largely determined by their performance at the near point. Only 9% gave any indication of problems associated with distance refractive error.

It is argued that the importance of binocular vision particularly at the near point can only be understood by measuring eye dominance and dominance type. Without this understanding there is an assumption that all reading difficulties are genetic in origin with the consequent streaming of similarly affected peers.

There is a general unawareness about where normal vision development occurs in evolutional terms, which is on the savannah. This lack of understanding is typified by a loss of school playing fields and the avoidance of competitive sport.

It may not be a coincidence that many of the children at Hemyock School almost all of whom suffer from near vision difficulties, come from a community of farmers whose excellent vision and the love of the outdoors is much closer to our evolutionary past than the visual demands of modern life and information technology (IT).

The visual system is not evolved to deal with hours of reading, computer use and use of the now ubiquitous and addictive smart phone. Increasingly society may be measuring a persons' ability to deal with near visual stress rather than their true academic and career potential.

A diagnosis of dyslexia may now be a barrier to understanding the extent of these difficulties. Reading (and learning) difficulties are increasingly thought to be genetic in origin where the only treatment is palliative.

A consideration of the results and coincident research in other fields has opened the possibility that Dyslexia is not due to a congenital dysfunction in central processing (brain damage) but a measurable and correctable binocular deficiency. A new test for reading speed is proposed which measures the comparative rate reading speed (CRST) between a Times font and a Gill Sans font. This would be accessible to form teachers to quickly identify and refer children at risk of optically correctible reading difficulties.

Keywords: *Dyslexia; Eye Dominance; CRST; Binocular Vision; Maxwell Spot Centroids; Dominance Type; Reading Difficulties; Reading Speed*

Abbreviations

SVUK: Sport and Schoolvision UK; ASvP: The Association of Sport and Schoolvision Practitioners; CRST: The Comparative Rate of Reading Speed Test; BV: Binocular Vision; UK: United Kingdom; RS: Reading Speed

Introduction

Screening is the evaluation or investigation of something as part of a methodical survey, to assess suitability for a particular role or purpose [1] (for example in Schoolvision screening, the need for a full eye examination).

Childrens' vision is important, and a visual disability can have a profound eaffect on their development. But there is no consensus on when or if children should be screened, which tests should be done or even what constitutes a visual disability. This particularly applies to vision screening in schools [2-7].

School screening

Traditionally the new school intake would have their vision measured by matron or the form teacher. The vision in the right eye and then the left eye would be measured using a Snellen chart at six metres or a letter-matching chart [1]. This test was unlikely to identify moderate hyperopia (<+2.00), lower levels of astigmatism (<-1.00), latent hyperopia (plano) or incipient myopia (-0.25). Even mild amblyopia (6/9) could be passed off as being within the range of normal vision. Only myopia over say -1.00, quite severe astigmatism (-2.50), hyperopia (+2.50) or amblyopia (6/24) might have been flagged up; there would be no consideration of binocular vision [7]. The incidence of high ametropia and manifest squint are rare in primary education [8] so it is understandable that this method of screening has fallen into disuse.

The lack of vision screening in schools is condoned in the UK because of the availability of a government funded sight test for anyone under the age of 16. The limitation of this service as a replacement for screening is that parents don't use it unless they have an underlying concern or are worried about the cost of spectacles. Children themselves may not be aware that they suffer from visual difficulties and after the age of 11 they are encouraged to become more self reliant and less likely to volunteer visual problems [8,9].

Importance of the teaching profession

Teachers have a comparative and disinterested view of their students and are expert in identifying children who are having difficulties, which increasingly can be attributed to vision [8,9]. With the help of the teaching staff school therefore remains the most important sector within which to screen children's eyes.

Current screening tests

The screening tests for ametropia and reading difficulties can vary, often taken from the range of tests used in general practice [6] and sometimes using less routinely used techniques (Auto-refraction [11], Cycloplaegia [7]) which eliminate the subjective response and distort normal physiology [12]. Sometimes Orthoptists who do not routinely refract or measure physiological muscle balance problems [13] will undertake the screening [14]. Some of these methods can give misleading results if gross tests designed to reveal pathology are used to describe more subtle physiological deficits [15]. In the extreme research using atropine to investigate the aetiology of myopia [16] may not take into account the multiplying effect of a pre existing accommodation insufficiency at an important time in the subjects' education.

Evolution of the schoolvision screening battery

Sports Vision grew in America from the work of behavioural Optometrists with children [18,19].

These colleagues found that in children with reading or behavioural problems, eye exercises or visual therapy could be beneficial. These could be straightforward orthoptic exercises or the practice of whole-body skills designed to enhance hand eye and body coordination. This approach has always been hampered by a lack of scientific evidence to demonstrate the long-term effect [20-22].

Eye exercises in sport

Athletes have been brought up in the belief that physical exercise can improve performance and although this is intuitively true, the scientific evidence is again hard to come by [23-25]. Nevertheless, athletes have always believed eyesight to be important [26], which has now been shown to be scientifically true [17].

The combination of the importance of eyesight and the intuitive understanding of the need for physical strength and endurance led to the belief that eye exercises can act as a panacea for improved athletic performance.

When sports vision was brought over to the United Kingdom from North America by Don Loran, founder of the original Sports Vision Association (SVA) he brought with him a battery of sport vision screening tests [27] (See also appendix 1 {Ap1} for examples of the original sportvision screening battery).

During the early days of SVA research 28 elite athletic groups were screened using these tests. There were up to 21 individual tests, which needed 10 Optometrists to screen a group of 25 athletes [28] (See appendix 2 {Ap2}, SVA and sport and schoolvision UK {SVUK} elite visual assessments undertaken).

At the end of a session there was an embarrassment of data but little idea of what to do with it, what it meant and how to explain any deficiency other than the idea of giving eye exercises.

However, these early screenings did produce some interesting findings, perhaps the most important being the incidence of eye dominance which coupled with hand dominance seem to vary from one sport to another (See table 1). This led to the original research in Sportvision, which was the key to a different understanding of the physiology of binocular vision, the causes of deficiency and therefore how to correct them [17].

Dominance		Cricket Scottish	Archery		Football	Rifle G.B. Junior
Eye	**Hand**	**National N = 15**	**Internationals N = 16**	**Coaches N =70**	**Leyton Orient N = 18**	**Squad N = 32**
Right	Right	46.7	62.5	84.3	55.5	87.5
Left	Left	6.6	18.75	10	11	3.1
Right	Left	6.6	6.25	2.85	16.7	0
Left	Right	40	12.5	2.85	16.7	9.4

Table 1: *The incidence of hand eye dominance in four different elite groups of athletes.*

The original hypothesis in this research was that if the incidence of hand eye dominance varies from one sport to another there maybe something about this configuration, which predisposes athletes to a particular sport. This led to the question, "What effect would it have on sporting performance if the dominant eye were blurred or fogged equivalent to normally occurring ametropia".

To test this hypothesis two groups of athletes were screened, former elite Wimbledon tennis players on the Masters' circuit and national and international clay target shooters at the Braintree Clay target club [29].

It was established in the initial screening that all the athletes had 6/6 vision or better in both eyes as they presented; their eye and hand dominance were measured by separate researchers using a hand over hand method (See appendix 1 {Ap1}, eye dominance figure Ap1h).

Each group of athletes was given a task (an analytical test) to measure the group's performance in a test, which represented a key skill in their respective sports.

The Clay Shooters were asked to shoot at the clay launched to about 30m (See figure 1). They took 30 shots in three different conditions of blur (about 6/15 using Bangerter foil in three pairs of shooting frames), the right eye fogged, then the left eye and then no blur. They scored 1 for a hit and 0 for a miss [29].

Figure 1: *The launcher for clay target shooting.*

The tennis players were judged by their ability to hit an archery target (See figure 2). They also had 30 shots in the same conditions of fogging, scoring 3 points if they hit the gold or the red, 2 for the blue or black, 1 for the white and 0 for a miss [29].

Figure 2: *The analytical test for tennis, using an archery target.*

Using these methods of scoring (analytical tests) the two groups of athletes were compared in each of the three conditions of blur.

Results of fogging in clay shooting

Initially in shooting when fogging of the dominant eye (whether it was the right eye or the left eye) was compared with no fogging there was no significant difference between the scores. The data was then divided into those shooters with a right dominant eye, right hand right foot and those with a left tendency in eye, hand, or foot. These two groups were defined Type I (Right eye, hand, and foot) and Type II (any left tendency in eye, hand, or foot). Type 1 was significantly affected when their dominant eye was fogged, and Type 2 was not.

IIn other words, shooters with a right dominant eye and right hand found it very difficult to hit the target when their right eye was blurred (fogged) a result, which for most shooters was obvious. What was not obvious was the effect on Type II's who were largely unaffected (statistically) regardless of which eye was blurred. Type I's were the best shooters but Type II's resilience may be due to less well-established dominance. This enables them with practice, to acquire the ability to aim with their non-dominant eye

Nevertheless, the effect on Type I showed scientifically possibly for the first time, that vision and sporting performance are be directly relatedlinked.

Results of fogging in tennis

In the tennis players unexpectedly, the whole group was significantly affected when their non-dominant eye was blurred, the opposite to the shooters. Separating the Types showed that this effect was again due to Type I. Type II were even less affected than Type II was in shooting. It seemed that the way the two eyes worked together (binocular vision) was key to understanding the relationship between vision and sporting performance (See table 2).

		Probability *(significant)*		
	Scores Fogged Eye (V No fogging)	**Whole group**	**Type I**	**Type 2**
Clay	Dominant (N = 7)	0.88	0.0057	0.083
	Non-Dominant (N = 7)	0.88	0.76	1
Tennis	Dominant (N = 7)	0.18	0.074	0.92
	Non-Dominant (N = 5)	0.0047	0.0053	0.33

Table 2: *Summary of the significance of unilateral fogging on sporting performance in clay target shooting and tennis. For significance $p < 0.05$ (two tailed T test equal variance).*

Aspects of these results in both sports were unexpected so what might be defined as the second primary skill (after aiming) depth judgment was considered. Random dot stereograms are used to measure the ability to judge depth (stereopsis) using two eyes.

Stereopsis

It is likely that stereopsis can only be optimised if binocular vision is fully established during the formative years, which arguably begin at birth. If there were impediments to the establishment of say 15" of arc on the TNO test (although there are different methods of measuring stereopsis [30]) the brain has to adapt to that deficiency. For instance, rather than completely relying on stereopsis to judge depth it will learn to use monocular clues like parallax, fade, and size to estimate the distance of the object.

Clay shooting and tennis both rely on good depth perception. In clay shooting it is important to know the distance of the Clay to judge its horizontal speed, but the results showed that knowing its position as judged by the dominant aiming eye in clay shooting is more important.

In tennis aiming seems hardly important so it must be the non-dominant eye, which has the critical effect. It follows that the role of the non-dominant eye is to judge distance, which reinforces an ability to anticipate the arrival of the tennis ball say (at the face of the racket). This implies that tennis is a sport of anticipation based on depth perception. Therefore, it might be concluded that stereopsis in tennis is the greater skill, for which finely tuned visual development is necessary.

Why is the non-dominant eye more important for depth judgment in tennis.

It is not initially clear why in two eyes with nominally equal acuities that depth perception is far more affected when the non-dominant eye is fogged (in Type 1).

This could be explained by the strength of right dominance in an optimised visual system. It seems that before anything else, apart from gravity, knowing where we are on earth is dependent of stable eye dominance. It seems likely that as stability degrades, it will become proportionally more and more difficult to judge where we are. In the extreme the catastrophic effect of sudden onset diplopia is testimony to this.

The circumstantial evidence is that nature intended us to be Type I, the best shooters were all Type I but they still need good depth perception; it may be that the development of depth perception is built on the rock of dominant eye stability.

This implies that when a distant object is fixated the dominant eye looks directly at it without deviation. The trace of the non-dominant eye forms the "hypotenuse" of a right-angle triangle to the "adjacent" trace of the dominant eye; the base of the triangle ("opposite" the apex) being the line drawn between the two eyes, the pupillary distance (See figure 3).

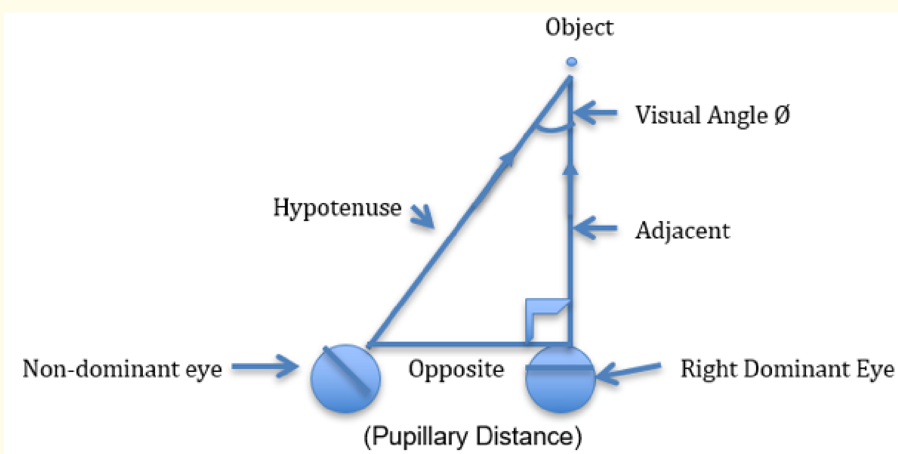

Figure 3: *Ray trace diagram for aiming.*

It is possible that the non–dominant eye can optimize depth perception given a sufficiently stable dominant eye, by searching the fixation point. This would explain why in normal binocular vision Floch and Ropars found the anatomy of the fovea in the non-dominant eye to be oval not round [31]. This would facilitate this microscopic search, which is dependent on the stability of the dominant eye. In subjects with equally round foveae there was a correlation to dyslexia and by implication poor binocularity and no developmental anatomy change in the non–dominant fovea.

This may be the first time a scientifically verifiable link between binocular deficit and dyslexia has been mooted.

The strength of eye dominance in tennis then is the gift that allows binocular vision to be fully established and depth perception maximised.

The effect of dominance stability

The dominant eye is so important in this primary role of aiming that it can overcome a degree of blur and still maintain stability. The non-dominant eye on the other hand might be regarded as a more subtle and sensitive partner in this relationship, which must not compete or override the dominant eye at the risk of loosing spatial awareness. In this case relatively little blur in the non-dominant eye would allow a much stronger dominant eye to swamp the visual system, effectively making the player monocular without being aware if it.

The stereoscopically dependent visual system In Type I tennis players has never needed to learn how to use monocular clues. Type II's on the other hand do not have the luxury of perfect binocular vision (because of an underlying instability in the dominant eye or binocular confusion caused by left handedness for example) so they have had to revert to monocular clues, which they can turn to when circumstances demand (like a fogged or refractively compromised aiming dominant eye).

Difference between type I and type II

It appears that the sports of clay shooting, and tennis require completely different visual skills. In Clay shooting it is aiming due to the dominant eye; in Tennis it is anticipation based on depth perception, which is dependent on the stability of the dominant eye and the sustained clarity of the non-dominant eye. It is possible that Clay Target Shooters are less physiologically suited to tennis than tennis players might be to shooting. Hence the physiological predisposition to certain sports, based on dominance Type and the proportion of the primary skills (Aiming and Anticipation - depth perception) required to compete in that sport.

Spacing The importance of aiming

Aiming is an integral part of life and will be called upon to a greater or lesser extent depending on the visual demands of the occupation or sport. The importance of that involvement can be estimated by the size of the target (visual task analysis).

The Importance of Target Size in Sport

The predominance of aiming and depth perception in sport could be predicted by the perceived size of the target, where the aiming requirement will be inversely proportional to the size of the target.

The perceived size of a target is a function of its size and distance from the observer, measured by the angular subtense it makes with the individual eye. It is possible for a small close object to have the same apparent size (angular subtense) as a much larger distance object further away. In clay target shooting the 11cm clay subtends an angle of 12' (minutes) of arc at 30m whereas in tennis the target (the other side of the court), makes a visual angle of 15^0 (degrees). This makes it possible to predict the proportion of these say "primary skills" (aiming and depth perception) in any occupation (See table 3).

	Shooting	**Tennis**		
Target	The Clay	Archery Target		Court
		Gold	Whole Target	
Target size (cm)	11	16	80	400
Distance (cm)	3000	300	300	1800
Tan ø	0.0037	0.0533	0.2667	0.2222
Angular subtense ø	12'	3°	15°	12° 33'

Table 3: *Target size (cm) and angular subtense at the eye in clay target shooting and tennis.*

The primary visual skill in reading

The ability to read is likely to start with the recognition of individual characters (letters), which precedes the ability to spell and read words and sentences or to guess and interpolate.

Individual N12 letters, read at 30cm say, subtend a visual angle of the order of size of the clay in shooting (See table 4). Seeing individual characters is therefore almost as difficult as it is seeing the clay [9]. For any reading task and individual, the distance of the text is likely to be fixed (requires no depth perception) which makes it likely that the primary visual skill in reading is aiming.

	Reading	Clay Target Shooting	Tennis
Target	N12 Letter (Gill Sans)	Clay	Whole archery target
Target size (cm)	0.2	11	80
Distance (cm)	30	3000	300
Tan ø	0.0067	0.0037	0.2667
Angular subtense ø’	23’	12’	900’

Table 4: *Relative target sizes in reading, clay target shooting and tennis.*

The importance of eye dominance in reading

If reading individual characters is the first building block in learning to read, it might be possible to redefine Reading Speed (RS) as the rate (speed) of reading a line of individual characters in seconds (the rate of individual character recognition). It follows that if there is a problem with the stability of the aiming dominant eye it is likely to affect the speed of individual character recognition [9]. A reduced RS is likely to affect academic skills like reading and mathematics where individual character recognition is important.

Exceptions

Good readers with reduced RS

Often children with a reduced RS say they are very good readers. Children who can’t easily fixate on individual letters can develop the ability to recognize a word by its first and last letters, making the order of letters between less important (See figure 4).

I cdnuolt blveiee taht I cluod aulaclty uesdnatnrd waht I was rdanieg The phaonmneal pweor of the hmuan mnid Aoccdrnig to a rscheearch at Cmabrigde Uinervtisy, it deosn't mttaer inwaht oredr the ltteers in a wrod are, the olny iprmoatnt tihng is taht ! the frist and lsat ltteer be in the rghit pclae. The rset can be a taotl mses and you can sitll raed it wouthit a porbelm. Tihs is bcuseae the huamn mnid deos not raed ervey lteter by istlef, but the wrod as a wlohe. Amzanig huh? and I awlyas thought slpeling was ipmorantt....

Figure 4: *Typo glycaemia.*

This leads to an ability (coupled with good and expanding peripheral awareness) to skim words and eventually sentences and paragraphs to take in large amounts of text very quickly (speed reading).

Speed reading and mathematics

Speed-reading is a valuable skill but can cause problems when individual characters (numbers) need to remain stable to do the simple addition of a column of numbers.

Speed-reading and detail

Individual words and their spelling are important in legal documents or scientific questions in exams.

Reduced RS but good at mathematics

Some children become good at math while remaining poor readers. Math starts with the basic skills of addition and subtraction. The visual task initially is short and the visual search for numbers easier [9], if concentration can be maintained long enough to keep the numbers in the right order the subject is rewarded by the correct answer. Once this interest is aroused motivation becomes easier as the questions get harder.

Reading does not give the same rewards (without the ability to speed-read). It may take 20 minutes to fully comprehend a short paragraph. If this has to be read and re-read to understand it's not long before the student will decide it's not worth the effort.

These exceptions are often dependent on a particular manifestation of intelligence on which RS is not dependent. One of the problems with current reading speed tests, is this confounding variable [9].

Measuring reading speed

In developing the Schoolvision screening battery it became clear that there was a need for a measure, which reduced the task of reading to its earliest developmental stage. This would avoid the complications of binocular adaptations including speed-reading and the ability to guess and interpolate (intelligence).

Once a certain level of visual acuity has been achieved one of the first things children are taught in school is the ability to recognise and copy individual letters. This could be measured by the ability to see and say these letters, but it also has to take into account the time this process takes. A convenient measure of reading speed might then be the time it takes to recognise and say individual letters (the rate of individual character recognition). In the CRST test (The comparative rate of reading speed test) this is refined by comparing the rates for 60 letters embedded in a paragraph using a Times font and a non-serif Gill Sans font. These fonts have been identified as having particular interest by the Dyslexia Association [9] and in this research, because of the difference in spatial frequency. It is has been shown that people with binocular difficulties will read the Times font slower than Gill Sans and people with poor visual development, uncorrected hyperopia, or accommodation insufficiency (causing reduced contrast sensitivity) will read the lower contrast Gill Sans font slower than Times [9] (See appendix 3 figure Ap3e).

The schoolvision screening battery

The screening battery of the diagnostic elements of occupational visual performance, was derived from the original 21 Sportvision screening tests. This battery of tests was unwieldy and too time consuming, so the question was asked which of these tests is critical in the context of the refraction (eye test) to identify the underlying cause of the visual deficit. These tests would have to be largely diagnostic, in other words they would represent one measureable aspect of visual performance and therefore be refractively correctable (See table 5).

	Test (generic)	Specific
1	Vision	High and low contrast LogMAR at 6m
2	Refraction	Distance and near retinoscopy (an estimate of refractive error)
3	Eye dominance	Hand over hand method [17]
4	Tracking	Schoolvision Standardised Dynamic Tracking [8],
5	Muscle balance	Objective muscle balance [33], cover test (near and Distance)
6	Sensory fusion	Fixation disparity [34], Rice Test [36]
7	Colour Preference and light sensitivity	The Eye Bright Test [35]
8	Accommodation facility	Added to reflect the near component of this research [8]
9	CRST	The analytical test, equivalent to the Archery target in Tennis (see Appendix 3 (Fig Ap3e) Examples of the new tests in the Schoolvision Battery [9]
10	Dynamic Fixation DFT	Static tracking, Intermediate/distance [17,38]

Table 5: *The schoolvision screening battery.*

CRST becomes the analytical test in the battery representing all the diagnostic tests as follows:

- Poor vision will make both fonts more difficult to read.
- Poor binocular vision and its effect of sensory fusion (The Rice Test) will make the high spatial frequency Times font more difficult to see.
- Refractive error will influence binocularity and contrast sensitivity.
- Poor binocularity or visual development will affect colour preference [35].
- Reduced contrast sensitivity will make the low contrast Gill Sans for more difficult.
- Reduced accommodation is likely to affect low contrast Gill Sans because of associated poor visual development (a level of amblyopia).
- Fixation losses with the standardized Schoolvision dynamic tracking test will be associated with accommodative convergence insufficiency and reduced speeds on the Dynamic Fixation test (intermediate static tracking also an analytical test) in turn an indication of a predisposition to dyspraxia (also dependent on the stability of the dominant eye).

The screening results based on the combination of the diagnostic elements and analytical tests would allow the children at risk of reading difficulties to be identified and referred to a qualified Schoolvision practitioner to carry out a full eye examination and refraction.

The target would be to eliminate any underlying pathology and supply glasses and/or contact lenses to correct the refractive and/orbinocular deficit. This would be done with an optical correction for distance or reading or both. Importantly this would then be managed under an eye plan scheme to monitor visual development, track refractive and prismatic changes and improvements in school performance (reading).

The Hemyock Screening

Objective of the Study

The aim of the research was to show that the proposed Schoolvision screening battery was able to demonstrate the incidence of visual deficiency in primary school children and predict the need for a full eye examination.

Materials and Methods

The research was carried out at Hemyock Primary School in Devon in 2016, 69 children of mixed ages underwent a vision screening. Most of years 3 and 4 and children from the other years (2,5 and 6 where their teachers had concerns), were screened. The screening took place in the school gym over three days, assisted by school staff who were taught how to use the battery of Schoolvision screening tests. Retinoscopy was carried out by the optometrist as the children presented with or without spectacles. Most of the tests are well known or described elsewhere some were new (See appendix 3 dynamic fixation [32], figure Ap3d, rice test, figure Ap3b [36], colour preference, figure Ap3a [35], eye dominance Ap3c [17,29]). Accommodation facility was assessed by a subjective response to a +1.00 binocular add.

Use of CRST (The comparative rate of reading speed test)

Speeds were taken to read the Times font aloud and then the Gill Sans font using lines of 60 characters imbedded in the two paragraphs, starting the stopwatch as the first letter was read and stopping it after the last (red) letter. Speeds were measured to the nearest hundredth of a second (See figure Ap3e [9]).

Scoring criteria

Every test including CRST with a poor (at risk) result was given a score of 1. There were 29 individual criteria in the tests, for instance Objective Muscle Balance was separated into Eso and Exo Phoria and Vision into right and left at high and low contrast on the LogMAR charts. The categorisation of at-risk criteria was assessed by considering the:

- Mean scores and standard deviation in that test
- The Moreton pilot study [9]
- Optical3 practice experience
- Subjects' own reported problems.

Expressions of probability

Statistical test used was a T Test. Probabilities of greater that 0.05 (equivalent to 5.00E-02) were not significant: P = 4.09E-08 (say) equivalent to p = 0.0000000409 (would be highly significant).

Results

Demographics

69 students from years 2, 3, 4, 5 and 6 were screened.

At risk children

Number of children with 5 or more at risk criteria in the combined diagnostic and Analytical tests = 69 (100%); ranging from 5 – 19 at risk visual criteria (See table 6).

Year	N	Mean	SD
Six	10	11.8	4.7
Five	8	12.12	12
Four	24	10.24	12
Three	22	9.82	10.24
Two	5	12	9.82
Total	69		

Table 6: *Number of children (N) screened in each year and the average number (mean) of "at risk" criteria in that year.*

Presenting signs and symptoms

Over half the group (56%) complained of one or more of the symptoms of light sensitivity, headaches or reading difficulties (See table 7).

Symptom	%
Light sensitivity	36
Headaches	22
Reading difficulties	32

Table 7: *Incidence of symptoms N = 50.*

Refractive error

The incidence of non-cycloplaegic distance refractive error was low (See table 8).

Condition	%
Significant Rx (N=9, astigmatism or incipient myopia)	8.95
Insignificant* distance refractive error (N= 61, range 0.0 to +1.5)	91.15

Table 8: *Incidence of distance refractive error.*

**Conventional understanding.*

CRST (Analytical results)

The speeds on the Times and Gill Sans fonts were compared for the whole group and there was no significant difference between them (p = 0.21).

When the subjects were divided into those with slower Times speeds than Gill Sans and those with faster Times speeds than Gill Sans the differences became significant. This was particularly true when Times was slower than Gill Sans (54% of subjects, p = 1.73E-08 e.g. p = 0.0000000173). When the Times speeds were faster the differences were still significant (46% of the subjects p = 0.00025). See table 9.

	Mean Speeds			
Speeds compared with Gill Sans when:	**Times**	**Gill Sans**	**% Diff**	**P**
Whole Group Analysed N=65	55.04	53.27	3.21	0.21
“Times” slower N=35	58.74	49.82	15.19	1.73E-08
“Times” faster N=30	50.71	57.3	11.49	0.00025

Table 9: *CRST speeds.*

Incidence of eye dominance and dominance type

Most subjects were Right eye dominant (52%). 10 students were equi-dominant, neither eye was clearly dominant (13%). The incidence of dominance Type, where equi-dominance counts as Type II (any left tendency) was Type I, 36% (Right eye Right Hand Right Foot) Type II (any left tendency) 64% (not all right eye dominant subjects were Type I) (See table 10).

	Eye Dominance			Type	
	R	**L**	**Equi-Dominant**	**I**	**II**
N	35	22	10	24	43
%	52.23	32.83	14.92	35.82	64.18

Table 10: *Incidence of eye dominance (N = 67).*

Effect of separating type I and type II

In Type1, 67% read the Times font slower than Gill Sans, p=3.62E-05 a significant indication of binocular vision difficulties. When their speeds were faster on the Times font than Gill Sans there was no significant difference between the two speeds (p=0.078) and, no significant difficulty caused by hyperopia or accommodation.

Type II showed an almost equal breakdown between those with slower Times speeds (48%) and those with faster Times speeds (51%), compared with Gill Sans. The differences between Times and Gill Sans speeds were significant in both cases (slower p = 7.95E-05, faster 1.12E-05).

In summary Type II were equally likely to suffer from binocular problems as trouble with hyperopia and accommodation (See table 11).

	Times Speeds (Compared with Gill Sans)	**% of Type (N)**	**P**
Type 1 N = 24	Slower	66.67 (16)	7.24E-05
	Faster	33.33 (8)	0.056 (5.63E-02)
Type II N = 43	Slower	48.84 (21)	5.75E-04
	Faster	51.16 (22)	5.01E-05

Table 11: *The effect of type I and type II physiology on rate of individual character recognition.*

The table suggests that Type I children who read the Times font as fast as the Gill Sans font were the least likely to suffer from a visual deficiency. These children represented 12% of the whole group. In other words, CRST which indicates that up to 88% of the subjects showed the predisposing signs to reading difficulty, supports the initial finding with the complete battery including the diagnostic tests.

Normative data for CRST

From the results a simple table of normative data can be proposed, but Teachers' experience in the use of CRST and knowledge of the individual child will also inform the decision to refer (See table 12). It seems that all Type 2's are predisposed to different levels of vision related reading difficulties, but Type I are more susceptible to binocular deficiency (67%), but less susceptible to developmental or accommodation related difficulties.

	Speed Secs	
Font	**Times**	**Gill Sans**
Good	< 40	< 38
Routine Schoolvision Exam	39 - 55	37 - 54
At Risk	> 56	> 55

Table 12: *Normative data for CRST speeds (Seconds) in primary education.*

Discussion

The school was very interested in helping all the children particularly those about whom teachers already had concerns in years two, four and five. This wasn't necessarily true about most of the group, but it was still a surprise to find all the children had five or more at risk criteria in the screening tests. Half of the group (56%) complained of symptoms like headaches or reading difficulties and light sensitivity, the remainder didn't volunteer any problems.

The analytical test CRST as an amalgam of the diagnostic tests was expected to show a difference between the Times and the Gill Sans speeds. Statistically slower speeds on the Times font for instance would have indicated a prevalence of binocular vision problems but the probability of 0.21 was not significant.

The effect of separating a tendency to binocular vision problems (Slow times speeds) from a tendency to reduced contrast sensitivity (Slow gill sans speeds)

When both sets of readings were separated into those with slower speeds on the Times font than Gill Sans and those with faster speeds on Times compared with Gill Sans the difference between fonts in these sub groups was significant; Times slower (probability that the Times font was read at the same speed at the Gill Sans = 1.73E-08), Times faster (p = 0.00025). This supports the proposal that CRST was able to measure and separate a tendency to binocular dysfunction (difficulty with the high spatial frequency of the Times font) and poor contrast sensitivity shown by difficulty with the low contrast Gill Sans font. It seems when these effects are not separated, they cancel each other out and confound the results.

The significance of the CRST findings then began to reflect the results of the diagnostic tests, particularly for the incidence of binocular vision problems.

The CRST test was built on the understanding and measurement of eye dominance where in this group 52% were right eye dominant, but only 36% were Type I. Further separating the subjects into Type I and II dominance showed physiological differences between the Types. The biggest difference for Type I was the difficulty they had with the high contrast Times font (induces pattern glare, p = 7.24E-05). The low contrast of the Gill Sans font didn't trouble them. Type II on the other hand had significant difficulties with the binocular vision (p=5.75E-04) and slightly more with reduced contrast sensitivity (p = 5.01E-05). It seems that determining dominant type is a useful guide to the type of visual problems that will affect students. This may help to determine which teaching method will be best suited to them, aside from the possibility of correcting these visual problems with glasses which will potentially have a levelling up effect on differently affected pupils.

The original research in sport established the importance of measuring eye dominance and differentiating between two different physiological Types, which has been supported by these results.

Eye dominance and dyslexia

Research has established the importance of stable eye dominance and the way in which distant objects will be fixated by the two eyes. This suggests the trace of the visual path from each eye to the distant object forms a right-angle triangle (See figure 3), with the non-dominant eye turning in slightly to gaze at the object. Unlike the dominant eye, which is fixed in position it leaves the potential for the non-dominant eye to search for the best focus on the object to refine the perception of depth with help from proprioceptive feedback in the extra-ocular muscles.

It follows that stereoscopic depth perception is built on the rock of stable eye dominance. It is possible to imagine a microscopic searching movement in the non-dominant eye, which might lead to anatomical changes in the developing fovea. If there were instability in the dominant eye due to a weak medial rectus say (decompensated divergence excess), this foveal refinement would be unlikely to take place. This is demonstrated by CRST in a corresponding reduction in reading speed on the Times font.

One of the characteristics of dyslexia is slow reading. In their separate study Le Floch and Ropars were able to demonstrate the asymmetry of the Maxwell spot centroids in non-dyslexics (the non-dominant fovea was oval) whereas in diagnosed dyslexics they were symmetrical (equally round).

This suggests that poor reading speeds are not coincident with the diagnosis of dyslexia but a direct result of dominant eye instability. The implications of this cause of dyslexia could be profound. It would change dyslexia from a congenital anomaly in the visual cortex ("brain damage") amenable only to palliative treatment, to condition where there is measurable weakness in one of the extra-ocular muscles, which is treatable refractively and/or with aligning prism. The effect of correction can then be measured by an increased speed of individual character recognition (Reading speed RS).

A new schoolvision screening test

Originally this paper was intended to show that the proposed battery of tests, which included CRST, was needed to highlight the children who were in greatest need of an eye test. At the same time the diagnostic tests would give an indication of the cause of the concern. What is emerging from this discussion is that CRST as the analytical test (an amalgam of the effects of the diagnostic tests) is sufficiently representative of the high incidence of at-risk diagnostic tests to make the referral decision. It is not necessary to diagnose the cause of the reading difficulties at the time of screening; this would be done at the time the eye examination using the newly established and existing diagnostic tests.

The practical advantage is that CRST becomes the only test that would be needed to screen children for a predisposition to reading difficulties. This includes children about whom their teacher may already have a concern, but also children who are apparently doing well but could be doing much better.

The subsequent eye examination would be able to correct the visual problems and monitor progress but perhaps reveal importantly those children whose difficulty has nothing to do with the binocular or developmental problems.

Using CRST the form teacher with a stopwatch would be able to screen all their children every six months if deemed necessary, taking no more than two hours for a class of 30 say, on each occasion. CRST is easily taught and takes at most three minutes to do. The decision to refer would be based on the normative data coupled with any existing concerns the teacher may have.

Conclusion

Up to 88% of the children at Hemyock School had the predisposing signs to reading difficulties. This was largely determined by their performance at the near point. Only 9% gave any indication of problems associated with a distance refractive error.

Binocular function particularly at the near point can only be measured through an understanding of eye dominance and dominance Type. This has potentially revealed the extent of the reading problem in primary school children. Education at all levels increasingly assumes that all subjects find it equally easy to read. The only concessions made are for diagnosed dyslexics.

There is a general unawareness about where normal vision development occurs in evolutionary terms, which is on the savannah, after the first visual lessons are learnt within the reach of the two hands. This lack of understanding is typified by the loss of school playing fields and the avoidance of sporting competition where stimulated by adrenaline development of the visual system accelerated.

It may not be a coincidence that many of the children at Hemyock School almost all of whom suffer from near vision difficulties, come from a community of farmers whose excellent vision and love of the outdoors is much closer to our evolutionary past than the visual demands of modern life and information technology (IT). Education has attempted to mirror the pace of change in IT.

It does not consider the unnatural stress and frailty of a visual system not evolved to deal with hours of computer use, reading, and addiction to the now ubiquitous smart phone. Increasingly society may be measuring a persons' ability to deal with near visual stress rather than their true academic and career potential.

The traditional diagnosis of dyslexia and its correlates may now be a barrier to appreciating the extent of these difficulties. Without a diagnosis a child may be deemed as having no difficulties with reading. For children with reading (and learning difficulties) the cause may be thought to be genetic for which the only treatment is palliative. In schools this may lead to inappropriate streaming with similarly measured peers.

A consideration of the results and coincident research in other fields has opened the possibility that Dyslexia is not due to a congenital dysfunction in central processing (brain damage) but a measurable and correctable binocular deficiency.

We now have the option with a measure of the comparative rate of individual character recognition (CRST) to screen all primary school children simply and quickly. The challenge will be to train Optometrists and Dispensing Opticians in this new understanding of Binocular Vision and related skills, which was never possible without measuring eye dominance and knowing the difference between Type I and Type II.

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Appendix (Ap) 1

Examples of the original sportvision screening battery

1. Anticipation timing using the Basin Anticipation Timer, and wall mounted Acuvision 1000 Dynamic Fixator (See figure Ap1(a)).
2. Peripheral awareness using the Peripheral Awareness Test available, see figure Ap1(b).
3. Stereopsis **-** (TNO) Measuring time taken as well as level achieved.
4. Vernier acuity Observation of a horizontal displacement in the middle of a vertical line.
5. Dynamic vision -Uses a peg board rotator, measures the minimum speed of rotation in cycles per minute to recognise a single letter, see figure Ap1(c).
6. Eye foot reaction time/Wayne Saccadic Fixator, see figure Ap1(d).
7. Hand Eye Reaction time, see figure Ap1(e) and (f).
8. Eye hand response time - using the Wayne Saccadic Fixator, see figure Ap1(g).
9. Eye dominance, see figure Ap1(h).
10. Accommodative facility Number of cycles per minute using -2.00/plano flippers looking at a 6m line of letters.
11. Vergence facility Number of cycles per minute using 2 base out/plano prism flippers looking at a 6m, vertical line of letters.
12. Contrast sensitivity - Vector Vision CVS 1000 available from Clement.
13. Eye foot reaction time - this measured the time of a simple reaction test to a light stimulus with left and right feet.
14. Vision - measured with high and low contrast logMAR Charts.
15. Glare recovery - measures the time taken to see a 6/6 line of letters after looking into a camera flash at 1m.

Figure Ap1(a)

Figure Ap1(b)

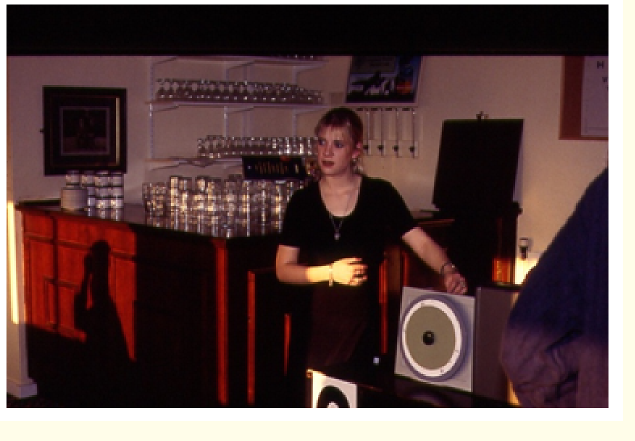

Figure Ap1(c)

Figure Ap1(d)

Figure Ap1(e)

Figure Ap1(f)

Figure Ap1(g)

Figure Ap1(h)

Appendix (Ap) 2 - SVA and SVUK Elite Visual Assessments

Sport	Team
Archery	The British National Archery squad.
Athletics	Winter Olympics in Lillehammer and the British Olympic Summer training camp Tallahassee (courtesy Bausch & Lomb).
Cricket	Loughborough University cricket academy 04/05
Cricket	The Scottish Cricket union97.
Cricket	Warwickshire County cricket 97
Cricket	Yorkshire County Cricket club
Cricket	Yorkshire Cricket Team.
Cricket	Loughborough University 1st team 06, 05
Football	East Derbyshire football academy 01
Football	Leyton Orient Football Club Senior
Football	Manchester City F.C. Football 97 Academy, U13 players
Football	Nottingham Forest U14 Squad 96.

Football	Squad.97•Ipswich Town Youth Team.
Football	The Lilleshall School of Soccer Excellence.
Football	Crewe Alexandra Football Club
Golf	English golf union 01
Golf Golf	English Ladies national golf squad 02 Welsh Womens' national golf squad 03
Hockey	British Women's Hockey team.
Motor racing	F1 Bar Honda 05
Netball	The All England Netball Association Panel Umpires
Shooting	Braintree Clay pigeon shooting club 03
Shooting	National and Junior Rifle Teams at Bisley.
Shooting	Scottish small bore rifle association
Snooker	147 Club Leicester 07
Squash	English Championships Sheffield 06
Tennis	Marsh Classic Tennis masters Hurlingham club London 03
Yachting	British Olympic Yachting Squad (Atlanta). 96

Figure Ap3(a): *Colour preference and high contrast LogMAR.*

Figure Ap3(b): *The rice test.*

Figure Ap3(c): *Eye dominance.*

Figure Ap3(d): *Dynamic fixation.*

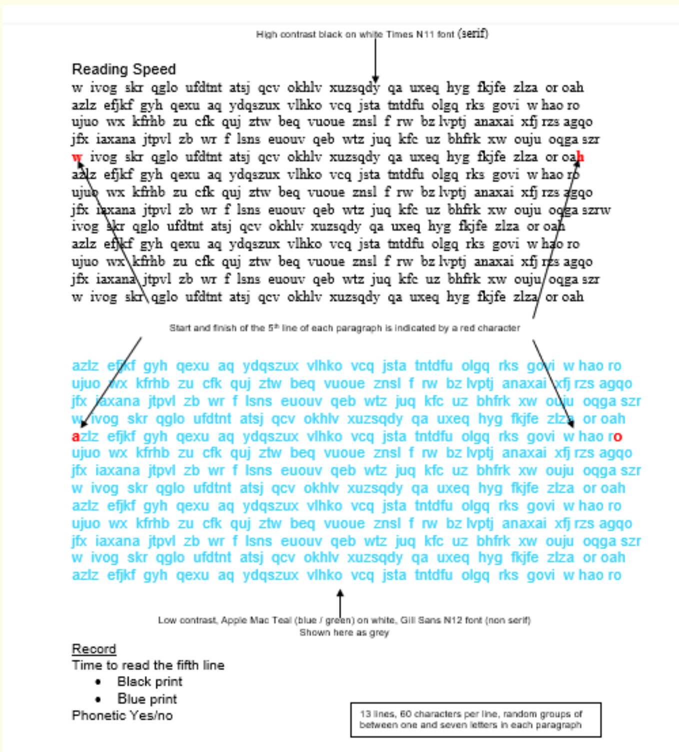

Figure Ap3(e): *Comparative rate of reading speed test (CRST).*

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