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Research article

The Effect of Optical Correction on Rate of Individual Character Recognition (Static Tracking) in Primary School Children

Geraint William Griffiths*

Chair of the Association of Sport and Schoolvision Practitioners (ASvP), Author of the Diplomas in Sport and Schoolvision Practice, Managing Director of SVUK Ltd., Sports Vision Expert to the British Standards Institute (BSI), General Practice at Optical3 in Leicester, UK

***Corresponding Author**: Geraint William Griffiths, Chair of the Association of Sport and Schoolvision Practitioners (ASvP), Author of the Diplomas in Sport and Schoolvision Practice, Managing Director of SVUK Ltd., Sports Vision Expert to the British Standards Institute (BSI), General Practice at Optical3 in Leicester, UK.

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Abstract

The children were originally screened using a battery of diagnostic (indivisible elements of visual performance) and analytical tests (an amalgam of the elements which represented a key skill in the occupation), including the comparative rate of individual character recognition between a "Times" and Gill Sans font (CRST). Those children as risk of reading difficulties were then tested (refracted) and their before (unaided) and after (with their prescription in a trial frame) CRST speeds were measured.

The screening confirmed that all the children had five or more at risk signs of reading difficulty. The CRST results showed 61% of the children had predisposing signs to binocular difficulties and 39% to difficulties caused by visual development. After correction those with binocular vision difficulties showed a 23% improvement in CRST speed on the Times font (p = 1.123E-07, N = 34)) rising to 26% after 5 months. Difficulties with visual development showed a 15% improvement on the Gill Sans font (p = 0.0008, N = 22) rising to 17% after five months. At the five-month interval the profile of the group had changed from predominantly binocular vision difficulties (60.7%) to a majority with visual development difficulties (60.6%).

The likely causes of reading difficulties included unstable eye dominance, accommodation insufficiency, reduced contrast sensitivity, ocular motor balance and cortical fusion problems, as well as straightforward refractive errors including anisometropia. Binocular dysfunction is cited as the primary cause of reading difficulties. Important signs of aetiology include a physiological anatomical displacement of the orbits and/or the globe (horizontal or vertical), accommodation insufficiency, accommodation excess and paresis in one or more of the extra-ocular muscles.

CRST was the more reliable and specific screening tool as a measure of binocular and developmental difficulties. This argues for a more refined approach to the refraction and binocular vision assessment, which takes into account the relationship between the accommodation/vergence reflex and eye dominance, and a direct relationship between vision and its affect on occupation. It is likely that this new approach to optometry will need a post-graduate qualification and professional safeguards.

Stress in the visual system caused by a constant need to access on line information is placing a load on visual physiology with which it is not evolved to deal. It is likely that the majority of the population is suffering from this problem, which is normal and part of the human condition. These problems can be corrected with spectacles and or contact lenses, associated tints and aligning prism.

Keywords: *CRST; Comparative Rate of Individual Character Recognition; Times Font; Gill Sans Font; Binocular Vision; Schoolvision; Prism; Differential Chromatic Occlusion; Fixation Disparity; Reading Speed; Developmental Difficulties; Visual Acuity; Dynamic Fixation Diagnostic Tests; Analytical Tests; Eyebright Test; Light Sensitivity; Contrast Sensitivity; Tinted Lenses; Reading Difficulties; Typoglycaemia; Auto-Refraction; Spectacle Correction; Refraction; Sight Test; Information Technology; Stereopsis; Eye Dominance; Aiming; Depth Perception; Drug Treatment; Tracking; Driving Standard; Ocular Physiology; Vision Screening; Information Technology; Myopia; Hyperopia; Convergence Insufficiency; Eye Exercises; Binocular Refraction; Divergence Excess; Rice Test; Ametropia; KPI; Key Performance Indicators; Foveal Ovaloid Maxwell Spots; Accommodation/Vergence Reflex*

Abbreviations

ASvP: Association of Sport and Schoolvision Practitioners; BSc: Bachelor of Science; BV: Binocular Vision; BSI: British Standards Institute; BVD: Binocular vision difficulties (Slow Times Speeds); CRST: Comparative Rate of Reading Speed Test; DD: Developmental difficulties (Slow Gill Sans Speeds); DE: Divergence Excess; DFT: Dynamic Fixation Test; FD: Fixation Disparity; G: "Gill Sans" Font; IT: Information Technology; KPI: Key Performance Indicators; M.ASvP: Member of the Association of Sport and Schoolvision Practitioners; MCOptom: Member of the College of Optometrists; MD: Managing Director; Mech. Eng: Mechanical Engineering; MSc: Master of Science; NHS: National Health Service; SVUK: Sport and School Vision UK Ltd; T: "Times" Font; UK: United Kingdom; UV: Ultraviolet; VA: Visual Acuity

Introduction

This paper is a continuation of "Vision screening in primary education (A cure for dyslexia?)" [1]. This paper follows the progress of the students from screening to sight test, for those at risk. The research was carried out at Hemyock Primary School in Devon in 2016, 69 children of mixed ages underwent a vision screening.

The physiology of vision and vision correction can be understood using the eight diagnostic elements of occupational visual performance [2]. These diagnostic measures derived from vision in sport [3] can be applied to every sport and all other occupations. They each represent a single characteristic of occupational visual performance, which is indivisible, measurable, and correctable in the process of a normal eye examination.

Two analytical tests were also included in the screening battery, Comparative Rate of Individual Character Recognition (CRST) [2] and Dynamic Fixation (DFT) [4]) (See appendix 1 The Schoolvision Screening Battery). Analytical tests are a way to measure a key element of occupational skill. A problem in carrying out the occupation would be mirrored by a deficit in the analytical test compared with other subjects in the peer group. The diagnostic tests would then be checked to pinpoint the cause of the occupational deficit.

Analytical tests are an amalgam of two or more of the diagnostic tests and represent an essential skill in the assessment of visually related occupation performance. DFT measures the effect of muscle balance problems on tracking in intermediate and distance occupations. CRST is the key analytical test in this study of the occupation of reading. Many analytical tests in sport for instance, would have to be designed for use on site [5]. Reading is an example of where the analytical test (CRST) is perfectly suited to indoor use. CRST was designed specifically for the Moreton secondary school study [6] and its successor in Hemyock primary school [7]. See appendix 2.

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

The CRST test has random groups of letters arranged into two paragraphs with different fonts (Times and Gill Sans) of 13 lines with 60 characters in each line. A red character marks the beginning and end of the two lines to be red (See appendix 5).

Speeds were recorded to read the Times and Gill Sans fonts aloud using the lines of 60 characters imbedded in the two paragraphs, marked by the red letters. The stopwatch was started as the first letter was read and stopped after the last (red) letter. Speeds were measured to a hundredth of a second.

Using the CRST test in practice it is possible to observe, categorise and quantify the signs and symptoms of binocular and developmental difficulties [8]. These appear to mirror the signs and symptoms of dyslexia (See appendix 3 sign and symptoms associated with reading difficulties and binocular deficiency). Previous research in the area [9-11] has not been able to find a link with vision and may be why the consensus persists that dyslexia is an incurable condition (disease) amenable only to drug [12] and palliative treatment (more time in exams, access to information technology {IT} equipment).

Purpose of the different fonts

The (serif) Times font gives an indication of binocular difficulties because of its higher spatial frequency (the serif part of the letters tends to make them merge when eyes are struggling to work together). In general, the non-serif Gill Sans font will always be read faster or the same as Times because of its lower spatial frequency. The exception to this rule is when subjects with reduced contrast sensitivity or poor visual development read Gill Sans slower because of its reduced contrast (teal font). For these reasons the true variable in the CRST test is contrast not font [2]. In this way the CRST differentiates between children with binocular vision problems (slow Times speeds) and poor visual development (slow Gill Sans speeds) and relates the degree of these difficulties to their rate in individual character recognition. The diagnostic elements of occupational (reading) performance are then measured and refined using a modified binocular assessment (See appendix 4) to determine the optical correction and cause of the reading difficulty.

The test was built on the concept that the ability to read is initially dependent on the recognition of, and ability to copy individual characters. Reading, even random words, or sentences can be corrupted by adaptations to a difficulty tracking from one individual character to another. Words can be recognised by their first and last letters, the jumble of letters in between do not have to be read singly (Typo Glycaemia) [2], making a standard method [13] potentially more a test of intelligence and adaptability than reading speed. The two different fonts were used to separate difficulties due to binocular instability, and poor visual development [2].

Occupationally specific tests (analytical)

Historically and for practical reasons occupationally specific tests have not been used in Optometry, which is why, a measure of vision has not been able to predict the effect of its correction on occupational performance. Without scientific support, however good the visual outcome of the refraction, an improvement in occupational performance cannot be claimed to be a benefit of the optical correction.

For the same reason blame cannot be easily apportioned legally to spectacles which may have contributed to a driving accident [14,15]. An example of this would be uncorrected divergence excess (eyes not coordinated in the distance), which can lead to loss of eye dominance (aiming) and depth perception particularly at dusk or facing oncoming traffic at night. The drivers' experience would be loss of positional sense and distance judgement. Without measuring eye dominance and demonstrating a direct relationship between vision correction and its effect on occupation this cannot be explained scientifically. A future measure of the driving standard will be based on a measure of eye dominance and is likely to vary from one individual to another [3].

As a result, the optical industry (the supply of bespoke spectacles and contact lenses) is supported by intuition and anecdote making it a target for people who do not understand its importance and value and the technology it depends on. This lack of accountability is gradually eroding the clinical credibility of the refraction and the eye examination and encouraging a separating move to automated refractions and specialisation in ocular pathology. The refraction is the unique skill of optometry which takes a lifetime to learn and will not be replaced by machine learning or automation [16]. The author has been in full time independent practice for 42 years and is only just beginning to understand (even as this paper was being written) the importance of binocular vision this new methodology.

The role of CRST

The role of CRST in this study is to identify subjects who have a deficit in their occupational performance (reading). The diagnostic test is to identifies the cause of that deficit. CRST may then be used to demonstrate the significance of a post refraction increase in speed.

At subsequent visits CRST can be used to show that the improvement has been sustained. The nature of binocular deficiency and mal adaptations is that once corrected, improvements should continue beyond those expected from age and experience. Once the eyes are aligned and visually corrected, improvements in central and peripheral neurology will continue slowly as the layers of consequential behavioural maladaptation (to the binocular deficit) fall away.

The first part of this research [1] established a broad agreement between the combined results of the diagnostic and analytical tests. The diagnostic tests showed that all the children screened had at least 5 deficiencies (See table 1 average number of at risk criteria in each year) where a full eye examination was indicated.

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 1: *Number of children (N) screened in each year and the average (mean) number of "At Risk" criteria in each Year.*

The CRST results indicated that all the children had binocular or developmental issues. When Times speed was slower than Gill Sans binocular deficiency was indicated. When Gill Sans was slower, visual development (problems with accommodation or hyperopia) would be the likely cause (See table 2 Hemyock CRST speeds [1]). The screening exercise was therefore able to identify children at risk (analytical test) with an indication of the cause of their difficulties (diagnostic tests).

Times v. Gill Sans	N	%	Times	Gill Sans	P
Times slower	35	53.8	58.74	49.82	1.73E-08
Times faster	30	46.2	50.71	57.3	0.00025

Table 2: *Mean CRST speeds Hemyock primary school screening N = 65.*

It is interesting to compare secondary to primary education where the incidence of binocular problems is 70% (See table 3 CRST speeds Moreton School screening [2,6]).

Times v Gill Sans	N	%	Times	Gill Sans	p
Times slower	65	70.7	41.38	34.95	6.84E-16
Times faster	27	29.3	33.11	35.11	0.00045

Table 3: *Mean CRST speeds Moreton secondary school (N = 92).*

The screening was a complicated exercise at both schools. Up to five members of staff had to be trained to use the tests and the screening was carried out over 4 days; the optometrist and research assistant needed to be present to supervise and support.

The prime objective was to identify children at risk. Confirming the cause and correction would then become part of the sight test for which the children were referred (the subject of this paper (See appendix 4 Summary of the binocular assessment and appendix 5 at risk diagnostic criteria).

At least 80% had problems on either the Times or the Gill sans font, which would predispose them to reading difficulties [2]. Taking Type I and II dominance into account only Type I when their speed was faster on Times than Gill Sans font (12%) were relatively low risk (See table 4 the effect of Type I and Type II physiology on the rate of individual character recognition).

	Times Speeds (Compared with Gill Sans)	% of Type (N)	% of the whole group (N = 67)	p
Type 1 N = 24	Slower	66.67 (16)	23.88	7.24E-05
	Faster	11.94 (8)	11.94	0.056 (5.63E-02)
Type II N = 43	Slower	48.84 (21)	31.34	5.75E-04
	Faster	51.16 (22)	32.83	5.01E-05

Table 4: *The effect of type I and type II physiology on rate of individual character recognition.*

The largely concurrent results for the screening tests, Diagnostic and analytical (CRST) raised the possibility that the analytical test on its own would be an effective screening method. Using CRST alone would simplify the screening process in the future and make it possible for the teachers to screen their own classes. A simple test to define the cause and cure of reading difficulties might help to reveal the true extent of this disability and prevent years of miss diagnosis with lasting effects on education, career, self belief and of inappropriate medication.

The test might also shed some light on other conditions like dyslexia where the signs and symptoms match those associated with binocular dysfunction (See appendix 6 Resolvable behavioural traits observed in children with binocular or development deficiencies during CRST reading speed measurement).

Another difficulty with alternative approaches to the reading problem is that there are no clear longitudinal sign to aetiology [17]. There is no acknowledged relationship to vision [10] or treatment regimen other than the use of differential chromatic occlusion [18], palliative care (more time in exams, help with IT equipment) or medication [12]. The screening [1] added to the weight of evidence supporting binocular dysfunction as the primary cause of reading difficulties [2,10,11,18-20].

In the first part of the research [1] a battery of screening tests was designed to identify children at risk of reading or learning difficulties (See appendix 1 The Schoolvision screening battery). The second part (this paper) aims to show that the original battery of screening tests can be replaced by the single analytical test CRST. And that this test provides a means to measure CRST reading speed before and after refraction, rates of individual character recognition which are dependent on restoring focus, and stable eye dominance.

Objective of the Study

To show that visual binocular and development deficiencies and associated light sensitivity affecting reading speed, are measurable using the CRST test and are optically correctable with spectacles and/or aligning prism and prescribed tints.

Materials and Methods

Null hypothesis

When significant differences in speed on the Times and Gills Sans fonts are demonstrated, predicting binocular or visual development deficiencies the resulting optical correction has no effect on the short or long-term ability to read (as measured by the comparative rate of individual character recognition CRST).

Method

The research was carried out at Hemyock Primary School in Devon in 2016. 69 children of mixed ages underwent a vision screening using the Schoolvision screening battery.

Binocular vision (BV) assessment of at-risk children

All the children screened appeared to be at risk of reading difficulties, so they were scheduled for a full binocular vision assessment. Parents whose consent was asked were informed that this was not a full eye examination and that the children should remain with their local Optometrists. Not all the children who were screened went on to have the assessment due to lack of consent, classroom logistics or leaving the school.

Testing procedure

As the students presented individually, their “Times” and “Gill Sans” CRST speeds were recorded by the research assistant. The researcher was out of sight and ear shot of the Optometrist. Once the presenting CRST speeds had been recorded the children were passed over to the optometrist for the binocular vision assessment, which drew on the screening data recorded on their individual record sheets and was recorded on the back of the data sheet.

The assessments took place in an improvised consulting room over a period of about three months in a school corridor (See figure 1 and 2, Test chart and Equipment, see in figure 1 with the lever arch file containing individual screening records {Appendix 7} on the sink). A summary of the routine non-cycloplaegic refraction and individual tests is shown in appendix 4. These results were written on the back of the data sheet in appendix 7.

Figure 1: *Test chart.*

Figure 1: *Test chart.*

Measurement of pre and post refraction CRST speeds

As the children presented their pre refraction Times and Gill Sans CRST speeds were measured by the research assistant.

After the refraction, the children were passed back to the research assistant to measure post refraction speeds with their correction in a trial frame. This was done at a table, which was separated visually from the refraction area. The subjects then chose their frames and were measured for heights and centres. The author processed the orders through his own practice in Leicestershire with the help of his dispensing colleagues and other staff members. As the completed spectacles were gradually brought back to the school, time was scheduled between on-going testing to re-measure CRST speeds with the fitted glasses. The immediate post refraction speeds are the data mostly used in the paper.

Five months follow on

After about 5 months (depending on when the glasses were dispensed) a follow on was arranged to check progress. As many subjects as possible were reassessed for CRST speeds with and without the spectacles.

At this point three sets of Times and Gill Sans readings were taken to check that familiarity with the test was not influencing the results:

- Without glasses
- With glasses
- And again, without glasses.

Although it was thought unlikely that 60 random letters in the CRST test would be remembered from testing. The same Times and Gill Sans letters were used in each trial.

Approval

Parental approval was given for each stage of the research and ethical approval given by the Association of Sport and Schoolvision Practitioners (ASvP). The parents and School were informed that this was not an eye examination and that they should continue to visit their own Opticians. Throughout the support of the school administratively and otherwise was critical to the success of the project.

Impartiality

The optometrist carried out the binocular assessments and refraction. The dispensing assistant measured reading speed with and without the new prescription and carried out all subsequent CRST speed measurements.

Expressions of probability (p)

Statistical tests used, T Test and Correlation. Probabilities of greater that 0.05 (equivalent to 5.00E-02) were taken as not significant: p = 4.09E-08 (say) equivalent to p = 0.0000000409 (would be highly significant)

The meaning of visual acuity (VA)

Visual acuity was an important consideration in this research particularly when measuring a subsequent improvement with time (due to more stable binocular vision or resolution of amblyopia). See appendix 8.

Results

Demographics

69 students were screened. Most of years three and four went through the battery of tests. Smaller numbers of students in years two, five and six who were screened particularly because of teachers' concerns, which will have influenced the percentage of children with difficulties. Some children had more than one pair or spectacles, for example reading and distance, or because of damage and rechecks (See table 5 demographics).

Item	Number (N)
Screened	69
Refracted (Spectacle prescription found)	58
Spectacles supplied	79

Table 5: *Demographics.*

Incidence of refractive conditions and binocular status

There was a high incidence of long sight 28% (> +0.75) and the low incidence of short sight 2% (anything less than plano). 14% showed signs of Divergence Excess. The most common deficiency was accommodation/convergence insufficiency (76%) which was corrected with prism and a reading addition (See table 6 Incidence of refractive conditions and binocular status).

%	Condition
2	Myopia
6	Astigmatism
6	Convergence insufficiency
14	Accommodation insufficiency
14	Divergence excess
28	Hyperopia
76	Accommodation /Convergence insufficiency

Table 6: *Incidence of refractive conditions and binocular status (N = 56).*

(Some conditions co existed).

At risk children

The number of children with 5 or more diagnostic and analytical at risk criteria = 69 (100%) which ranged from 5 - 19 (See appendix 5 tests and at risk criteria). All but two showed the need for spectacles at near or distance or both.

Although both sets of screening data diagnostic and analytical when separated, point to a high incidence of visual disability, they were not correlated (See table 7). This was calculated retrospectively from the screening data.

Correlation Risk V CRST, N = 68	
Times	Gill Sans
-0.190	-0.120

Table 7: *Correlation of the incidence of at-risk diagnostic results to CRST (analytical) speeds.*

Correlation with vision

The diagnostic measure of the mean of right and left LogMAR visions (particularly at low contrast) was correlated with CRST but only on the Times font (See table 8).

	Contrast	
	90%	**10%**
Times (p)	-0.041	0.016
Gill Sans (p)	0.168	0.284

Table 8: *Correlation of CRST speeds with binocular LogMAR vision (mean of R&L) at high and low contrast.*

The effect of spectacles on reading speed (CRST)

For the whole group 91% of the children (N = 56) showed an increase in either the Times, Gill Sans or both fonts with their spectacle prescriptions in the trial frame.

For the whole group the difference between Times and Gill Sans speeds as the children presented before the testing was not significant (p = 0.208), indicating an even mix of developmental (DD) and binocular vision difficulties (BVD). The significance of the two conditions only became apparent when they were separated.

Based on CRST research reduced speed on the Times font relative to Gill Sans defines BVD problems, reduced speeds on Gill Sans defines DD problems. This was the basis on which the group as divided:

- Binocular vision difficulties (BV) - slow Times speeds
- Developmental difficulties (DD) - slow Gill Sans speeds.

After testing in those with BV difficulties (60.7% N = 34), Times reading speed improved by 23.26% on average (p = 1.123E-07). Where there were developmental issues (33.9% N = 22) the improvement in "Gill Sans" speed was 15.52% (p = 7.99E-04).

With Specs there was no significant difference between the Times and Gill Sans Speeds in the BVD group (p = 1.09E-01) or the DD group (p = 0.0853). See appendix 9 for detailed tabulations.

Five months follow up

At the five months follow up the overall improvement in the BVD group (compared with the initial unaided speed at the time of testing) with the glasses was 26.17%. Gill Sans speeds in this group showed a 3.6% improvement. The Gill Sans in the BVD group without correction improved by 18% compared with the original unaided speed at the time of testing. The DD group improved by 14.9% on the Times font and 19.1% on Gill Sans with their glasses.

The incidence of BVD and Developmental difficulties (DD) had reversed at the time of the follow up compared to the original testing (See table 9).

	At Testing	Follow up
BVD	60.7% (N = 34)	39% (N = 13)
Develop (DD)	39.3% (N = 22)	60.61 % (N = 20)

Table 9: *Incidence of BVD and DD issues.*

Comparison of 1st and 3rd speeds

At the five month follow up there was no significant difference between the (without spectacles) first and third readings. First and third Times speeds (no correction) in the group with binocular vision difficulties approached significance ($p = 0.0938$).

Difference between Times and Gill Sans speeds

At the follow up the difference between Times and Gill Sans speeds without spectacles in the two groups (BVD and DD) has reduced compared to observed results at the time of testing. With the spectacles the differences for the binocular group between Times and Gill Sans speeds were not significant, Gill Sans speeds remained relatively unchanged. In the BVD group at follow up their spectacles made Gill Sans more difficult ($p = 0.0109$) (See appendix 9a and 9b).

The incidence of prescribed prism

39 subjects (78%) showed an improvement in Times or Gill Sans speeds when there was a prescribed prism.

Prism prescribed was mostly Base IN, no other prism was given other than 1 Base UP L at distance and near in two different subjects. More prism was given in the Right eye than the Left (Mallet rarely indicates that prism should be split equally between the eyes) although this difference is not significant (See table 10).

	R	L	
Distance	5	6	
Near	36	24	($p = 0.182$)

Table 10: *Incidence of base IN prism.*

Discussion

One of the conclusions of the screening report was that the analytical test CRST could be used to replace the diagnostic tests to simplify the screening process. This was justified because both sets of data pointed to the same degree of risk, but the two sets of data were not correlated.

The reason may be apt. This research has it roots in the need for a better understanding of binocular vision and the relationship between accommodation and vergence. Diagnostic measures like refraction, muscle balance and fixation disparity may be hiding binocular problems, which the more specific and sensitive CRST reveals. Emmetropia (latent hyperopia) for instance could be the result of a battle between hyperopia and divergence excess where the former is used to control the latter. Similarly, convergence insufficiency can be well controlled using an accommodation insufficiency, even turning the near muscle balance into an eso-phoria where the eyes move in the opposite direction to the underlying weakness. This often showed up with contradictory results on objective muscle balance and Rice fixation disparity (stimulates accommodation)

Eye exercises

It raises the possibility that exercises given to help convergence insufficiency may be acting on the ciliary muscle not the medial recti adding to the futility of this approach.

Hidden binocular difficulties

If CRST were to add anything to this new understanding it might have been disappointing to find a correlation between the diagnostic and analytical tests.

Earlier research in Moreton School described in the CRST study showed that one of the biggest binocular problems was accommodative/convergence insufficiency. Subsequently in practice as the understanding of the importance of binocular vision has been unraveled, awareness of the prevalence of divergence excess (DE) and its sometimes devastating effects has grown. DE is difficult to measure and requires a refinement of the Mallett test, which is beyond the scope of this paper but dependent on eye dominance.

It is likely that many of the true difficulties are hidden by spurious adaptations creating binocular instability, which required refined techniques using the diagnostic tests to elucidate. CRST itself is designed to reveal the presence of binocular instability with a greater level of sensitivity than the individual diagnostic tests.

Therefore, it still seems reasonable to consider CRST as the screening tool not just for speed and convenience but because it seems to be a better way to screen for the possibility of underlying binocular and developmental visual difficulties. Its correlation with perhaps the most important diagnostic test of LogMAR vision supports this argument. The diagnostic measures were still be needed to steer the direction of the subsequent eye examination, which then took on the greater responsibility of prescribing prism, amongst other refractive considerations.

Overall objective

This clarified the purpose of this paper. CRST may have a unique position in the screening of children's eyes. The results demonstrated that children who had slow CRST speeds were also likely to have the pre-disposing signs and symptoms of binocular instability and visual development problems. This was demonstrated after a refined refractive routine produces a prescription that significantly increased the rate of individual character recognition. For this reason, the null hypothesis was rejected.

Correlations to vision

The uncomplicated measure of LogMAR vision was correlated with CRST "Times" speeds at high and low contrast. "Times" is the font that defines binocular vision difficulties (BVD) so it underlines the importance of vision in the understanding of binocular deficit. There was no correlation with "Gill Sans" speeds, which define visual development difficulties, which helped to justify separating them from BVD. The importance of these finding, parallels the original research into eye dominance, which showed for the first time that vision and sporting performance were inter-dependent.

The need for a modified binocular refraction and post-graduate training

Whatever the cause of reading difficulties, BVD or developmental the correction of the diagnostic deficiencies was informed by both.

An understanding of eye dominance and the accommodation vergence facility changes this refractive process and obviates the apparent un-informed need for eye exercises. It establishes scientifically a direct connection between vision and occupation, which explains and justifies the optical correction.

This does imply that the standard approach to the refraction required by NHS key performance indicators needs modifying. It needs to take into account a more detailed physiological assessment of binocularity, as opposed to looking for gross pathological binocular deficit.

CRST validation

This paper then concentrated on validating the CRST test as a means of screening children to find those at risk of reading difficulties.

Comparisons between "Times" and "Gill Sans" CRST speeds

Comparing Times and Gill Sans CRST speeds became a useful tool for measuring progression.

When the unaided speeds for the two fonts for the whole group were compared there was no significant difference between them. When Gill Sans speeds were subtracted from Times speeds and ranked (the greater the numerical amount the slower the speed), the data divided into two. A positive result indicated slower Times speeds and a binocular difficulty. A negative result showed problems with visual development and reduced contrast sensitivity (slower Gill Sans speeds). The difference between the unaided Times and Gill Sans speeds in these two subgroups then became significant. In the unaided data for the whole group the two different problems of equal incidence had statistically cancelled each other out.

Splitting the data into binocular and developmental vision difficulties

After these two subgroups had been corrected the difference between the Times and Gill Sans speeds in each group (particularly in the group with binocular difficulties) were no longer significant. But this time it was because the speeds were the same. The spectacles had corrected the binocular and developmental difficulties. This was supported by the significant effect that the optical correction had on CRST reading speeds. It also confirmed a the expected convergence of Times and Gill Sans speeds as the optical problems were corrected.

The significance of the "Times" font

The Times font in particular seemed to be the main driver in the disparity with Gill Sans. As the performance improved, speeds on Gill Sans remained largely the same it was the Times speeds which became faster. This is a clue to the power and significance of the ubiquitous "grown up" Times font, which may have a lot to answer for.

Test retest reliability

There was no significant difference between the first and the third CRST speeds (where no correction was worn) at the five-month follow up. However, the Times speeds for children who initially had difficulties with binocular vision did approach significance ($p = 0.094$). The quicker recovery of BV subjects who were not hampered by developmental problems may have made it easier to remember some of the patterns of letters at the beginning and end of the line. If repeated measures of speed are needed to confirm an addition or prism correction it might be necessary to use a different line of letters with the Times font.

Generally, it is unlikely that subjects will remember 60 letters after a first reading if they are already struggling to read. Using the same lines of letters otherwise did help to standardise the test.

The aetiology of reading difficulties

Inspection of the individual sight test results and corresponding increases in CRST speeds helped to quantify the incidence of specific vision problems within the groups.

Uncomplicated hyperopia was normal in this cohort and myopia rare. The results refuted the general assumption that children do not have accommodation problems (accommodation is not a key performance indicator {KPI} in the National Health Service {NHS} eye examination).

The results showed that convergence insufficiency on its own (the only BV condition that is thought to be amenable to eye exercises) is rare and that divergence excess ("untreatable") is more common. The surprise was how frequently accommodation/convergence insufficiency occurs. This condition can only be corrected using a combination of plus lenses, prism, measured fixation disparity and a knowledge of the importance of eye dominance. Other important signs of aetiology also followed. These include, a physiological anatomical displacement of the orbits and/or the globe (horizontally or vertically), accommodation insufficiency, accommodation excess, and paresis in one or more of the extra-ocular muscles often complicated by the sequalae of these extra-ocular adaptations.

Effect of age

In the mixed year groups (two to six) of the children there might have been an opportunity to show a correlation between their age in months and CRST reading speed. There was no correlation. Intuitively it would be reasonable to expect a steady improvement in all aspect of childrens physiology with time. The fact there was none in Hemyock School may be itself and indication of the extent and diversity of these visual difficulties. A more meaningful assessment of physiological development might be achievable after the visual problems have been corrected.

5 month follow up

After about 5 months the spectacles in the BVD group continued to make reading easier on the Times font (17.1% improvement with the spectacles, p = 1.12E-07). On the Gill Sans font the subjects read significantly better without the spectacles (p = 0.011). It appears that although the binocular difficulties have been largely corrected there is still some legacy of visual development, which makes the low contrast font more difficulty to see. This would require future monitoring to see if contrast sensitivity (amblyopia) improves with time and continued wearing of the spectacles.

The DD group still showed significant improvement on both fonts from a faster base than at testing. Their performance on the Times font has improved since it was measured first after the test. This suggests that binocular vision does depend on visual development (vision) even though it is not related to binocular deficiency.

This would support an argument that the spectacles have improved visual acuity (a resolution of amblyopia). And again supports the original premise that Times will invariably be read slower or the same as Gill Sans provided there is no other barrier to reading speed (poor contrast sensitivity).

Incidence of ametropia in primary and secondary education

A final set of statistics might be useful to inform the debate on the aetiology of ametropia. A comparison of the incidence of myopia in the two Schools screenings Moreton and Hemyock showed an increase in myopia from 3.08% in Hemyock to 18.33% in the first year of secondary education in Moreton School.

The Moreton children were still only 11 years old, when a typical presenting age for acquired short sight is anecdotally around 14 or 15; what makes myopia increase so rapidly in such a short space of time. A clue may be the high incidence of combined accommodation and vergence problems in Hemyock School. This lays the foundations for a consequential stretching effect on the globe. This is exacerbated with the over use of personal computers and smart phones as pressure on education intensifies up to and beyond secondary school admission.

Conclusion

A summary of the diagnostic results confirmed that all the children had five or more at risk signs of reading difficulty. Analysis of the CRST results (Comparative rate of individual character recognition) showed 61% of the children had predisposing signs to binocular difficulties and 39% to difficulties caused by visual development. After correction of those with binocular vision difficulties showed a 23% improvement in CRST speed on the Times font (p = 1.123E-07, N = 34)) rising to 26% after 5 months.

Difficulties with visual development showed a 15% improvement on the Gill Sans font (p = 0.0008, N = 22) rising to 17% after five months. At the five-month interval the profile of the group had changed from predominantly binocular vision difficulties (60.7%) to a majority with visual development difficulties (60.6%), both still showing significant improvement with their spectacles from a faster base.

Inspection of the testing results made it possible to identify the likely cause of the reading difficulties. This included unstable eye dominance, accommodation insufficiency, reduced contrast sensitivity, ocular motor balance and cortical fusion problems, as well as straightforward refractive errors including anisometropia. With this report the weight of evidence to supporting binocular dysfunction as the primary cause of reading difficulties is growing. Important signs of aetiology have emerged. These include, a physiological anatomical displacement of the orbits and/or the globe (horizontal or vertical), head tilt, accommodation insufficiency, accommodation excess, and paresis in one or more of the extra-ocular muscles.

CRST appears to be a reliable screening tool as a measure of binocular and developmental difficulties. The subsequent more refined approach to the refraction and binocular vision assessment, took into account the relationship between the accommodation/vergence reflex and eye dominance, and between vision and it affect on occupation. It is likely that this new approach to optometry will need a post-graduate qualification and professional safeguards.

The human condition

Stress in the visual system caused by a constant need to access and use on line information is placing a load on visual physiology with which it is not evolved to deal. It is likely that the majority of the population is suffering from this problem, which is normal and part of the human condition.

These problems were identified during the binocular assessment and corrected with spectacles and or contact lenses, associated tints and aligning prism.

Prevention of acquired ametropias

There seems to be a compelling argument to test and correct primary school children to help prevent the establishment of acquired ametropias, which now seems to be a “natural” progression with age. The critical age for screening in primary schools might be year 4 when refractive findings were most reliably assessed and the first year of secondary education.

For secondary schools year seven is the time when children are at their most vulnerable, away for the close support of their primary school teacher and having to fend for themselves in a sink or swim situation. This is the period when aberrant behaviours are most likely to develop as students find their own ways to adapt, conform and hide their real feelings. This is a period when authority is less likely to have time to respond to individual difficulties or attribute them to solvable visual problems, which in any case the standard NHS examination is not designed to elucidate.

This does not prelude individual referrals at any age when teachers are concerned or CRST results indicate.

A need for a better understanding of binocular vision

The weight of evidence is now building for a better understanding of the importance of binocular vision and it effect on reading. The relationship between unstable eye dominance and CRST speeds has lead to a simple correction of reading difficulties with an optical and/or prismatic correction. It can be argued from first principles that the strongest predisposing sign to reading difficulties is a fixation disparity in the dominant eye.

The use and usefulness of tinted lenses comes from their association with binocular deficiency and light sensitivity. The effect of darkly tinted lenses with their potentially adverse effect on colour perception and contrast sensitivity is more difficult to understand. It may be due to "Differential Chromatic Occlusion" in pre-existing binocular deficiency where the weaker eye is turned off (suppressed or occluded), thereby removing the binocular conflict (which causes the reading difficulties). The "Wilkins" effect may be diagnostic of significant binocular deficit.

The effect of binocularity on foveal anatomy

The importance of dominant eye stability has established that the two primary visual skills in sport and all other occupations are aiming and anticipation (based on depth perception). From this understanding it can be argued that the most important primary skill is aiming, which needs to be established first (the rock on which all visual occupational skills are built), before depth perception can be maximised. From this point of stability the non-dominant eye is then able to establish true stereopsis. This is built on the "Right angle triangle" understanding of the way the two eyes fixate a distant object. Against the fixed dominant eye the other eye is able to search the fixation point, including proprioceptive feed back from the extra ocular muscles, to optimise the perception of depth.

Using this model it could be predicted that the fovea of the non-dominant eye would develop an increased range of sensitivity, which changes its anatomy. Flock and Ropars have demonstrated the presence of "Foveal Ovaloid Maxwell Spots", which are not present in diagnosed dyslexia. It appears that a characteristic of normal binocular development is an oval non-dominant fovea. Where there is unstable binocular vision there tends to be two round foveae. In other words a characteristic of binocular deficiency is unstable eye dominance, which prevents this anatomical change.

Other methods of assessing reading difficulties

It is interesting to note that other methods of assessing reading difficulties describe signs and symptoms, which mirror those of binocular deficiency. The optical approach to reading difficulties (Optometry and Dispensing Optics) in this report suggests that vision and reading speed are directly related. And that speed improves when binocular problems and visual difficulties have been corrected with spectacles.

A binocular understanding explains why eye exercises are not supported scientifically. It offers an explanation of why brain scans can show signs of increased local activity, which may be due to difficulties processing two disparate images caused by unstable binocularity.

The concern is that without a clear understanding of the aetiology of binocular and developmental visual deficit, medicine tends to treat the "incurable" consequences as a disease process amenable to drug treatment. Without a precautionary visual assessment this could lead to inappropriate life affecting therapies.

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Conflict of Interest

There are no conflicts of interest.

Appendices

Appendix 1: The Schoolvision Screening Battery

	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 [a]
4	Tracking	Schoolvision Standardised Dynamic [b],
5	Muscle balance	Objective muscle balance [c], cover test (near and Distance)
6	Sensory fusion	Fixation disparity [d], Rice Test [e]
7	Colour Preference and light sensitivity	The Eye Bright Test [f]
8	Accommodation facility	Added to reflect the near component of this research [b,g]
9	CRST (Analytical)	The analytical test, equivalent to the Archery target in Tennis [eye dominance)
10	Dynamic Fixation DFT (Analytical)	Static tracking, Intermediate/distance [h]

Appendix 1: References

a	Griffiths GW 2003 Eye Dominance in sport - a comparative study Optometry Today Vol 43:16 15.8.03
b	The Moreton Study published SVUK available 9 Leicester Road Anstey LE7 7AT 0116 236 3113 www.sportvision.co.uk
c	Von Graefe http://www.ophthalmictechnician.org/index.php/tech-tips/161-maddox-rod-or-von-graefe
d	Mallet R.F.J. (1964) The investigation of heterophoria at near and a new fixation disparity technique. Optician 148; 3845: 573-581
e	Rice J 2017 The significance of the Brock String. Journal of Sport and Schoolvision Autumn 2017 Published SVUK available www.SVUK.info/contact 0116 236 3113
f	Geraint William Griffiths. 2021 “The Aetiology of Colour Preference and its Association with Light Sensitivity, Reduced Contrast Sensitivity and Binocular Deficiency” EC Ophthalmology 12.6.(2021): 16-31.
g	Keirl A, Christie C 2007 Accommodation (p 155) in Clinical Optics and Refraction, Pub Elsevier Ltd
h	Griffiths GW 2002 Eye speed, motility and athletic potential. Optometry Today Vol 42:12 14.6.02

Appendix 2: The comparative rate of reading speed test (CRST)

CREST

Patent applied GB 1303234.7

Comparative Reading Speed Test (1)

w ivog skr qglo ufdtnt atsj qcv okhlv xuzsqdy qa uxeq hyg fkjfe zlza or oah
azlz efjkf gyh qexu aq ydqszux vlhko vcq jsta tntdfu olgq rks govi w hao ro
ujuo wx kfrhb zu cfk quj ztw beq vuoue znsl f rw bz lvptj anaxai xfj rzs agqo
jfx iaxana jtpvl zb wr f lsns euouv qeb wtz juq kfc uz bhfrk xw ouju oqga szr
w ivog skr qglo ufdtnt atsj qcv okhlv xuzsqdy qa uxeq hyg fkjfe zlza or oah
azlz efjkf gyh qexu aq ydqszux vlhko vcq jsta tntdfu olgq rks govi w hao ro
ujuo wx kfrhb zu cfk quj ztw beq vuoue znsl f rw bz lvptj anaxai xfj rzs agqo
jfx iaxana jtpvl zb wr f lsns euouv qeb wtz juq kfc uz bhfrk xw ouju oqga szrw
ivog skr qglo ufdtnt atsj qcv okhlv xuzsqdy qa uxeq hyg fkjfe zlza or oah
azlz efjkf gyh qexu aq ydqszux vlhko vcq jsta tntdfu olgq rks govi w hao ro
ujuo wx kfrhb zu cfk quj ztw beq vuoue znsl f rw bz lvptj anaxai xfj rzs agqo
jfx iaxana jtpvl zb wr f lsns euouv qeb wtz juq kfc uz bhfrk xw ouju oqga szrw
ivog skr qglo ufdtnt atsj qcv okhlv xuzsqdy qa uxeq hyg fkjfe zlza or oah

azlz efjkf gyh qexu aq ydqszux vlhko vcq jsta tntdfu olgq rks govi w hao ro
ujuo wx kfrhb zu cfk quj ztw beq vuoue znsl f rw bz lvptj anaxai xfj rzs agqo
jfx iaxana jtpvl zb wr f lsns euouv qeb wtz juq kfc uz bhfrk xw ouju oqga szr
w ivog skr qglo ufdtnt atsj qcv okhlv xuzsqdy qa uxeq hyg fkjfe zlza or oah
azlz efjkf gyh qexu aq ydqszux vlhko vcq jsta tntdfu olgq rks govi w hao ro
ujuo wx kfrhb zu cfk quj ztw beq vuoue znsl f rw bz lvptj anaxai xfj rzs agqo
jfx iaxana jtpvl zb wr f lsns euouv qeb wtz juq kfc uz bhfrk xw ouju oqga szrw
ivog skr qglo ufdtnt atsj qcv okhlv xuzsqdy qa uxeq hyg fkjfe zlza or oah
azlz efjkf gyh qexu aq ydqszux vlhko vcq jsta tntdfu olgq rks govi w hao ro
ujuo wx kfrhb zu cfk quj ztw beq vuoue znsl f rw bz lvptj anaxai xfj rzs agqo
jfx iaxana jtpvl zb wr f lsns euouv qeb wtz juq kfc uz bhfrk xw ouju oqga szrw
ivog skr qglo ufdtnt atsj qcv okhlv xuzsqdy qa uxeq hyg fkjfe zlza or oah
azlz efjkf gyh qexu aq ydqszux vlhko vcq jsta tntdfu olgq rks govi w hao ro

Record

Time to read the fifth line

- Black print
- Blue print

Phonetic Yes/no

www.sportvision.co.uk

(Not to scale)

Appendix 3

Behavioural traits observable in children with binocular or development deficiencies whilst CRST reading speed is measured [a, b].

Method

Reading speed is measured in two stages. First the time is recorded to read one line of 60 characters imbedded in the top paragraph (the 5th line down); this is the high contrast serif optotype (Times). Then the subject reads a second line in the bottom paragraph (5th line down) and the time is recorded; this is the low contrast teal colour non-serif optoype (Gill Sans).

In addition to recording the times any distinctive behavioural traits (clinically significant signs) should be noted, these might include:

- Following the text with the finger or thumb
- Marking the beginning of the line with the thumb
- Reading characters inaccurately
- Missing out characters
- Re-reading or loosing the place
- Head postures (eg head tilt or chin elevation)
- Heightened anxiety, excessive body movement
- Indications of tension in body language or breathing
- Gripping and re-gripping the test card
- Facial contortions
- Voice or body tremor
- Saying the characters phonetically
- Saying the characters phonetically for half the line
- Inability to read any or more than a few characters
- Test card held "too close," (closer that 10 cm)
- Test care held "too far" away (greater that 30 cm)
- Rapid fatiguing
- Big sigh when reading finished.

Appendix 3: References

a	The Moreton Study unpublished report. Available at SVUK Ltd 9 Leicester Road Anstey LE7 7AT 0116 236 3113 www.sportvision.co.uk The Moreton Study published SVUK. Available at SVUK Ltd 9 Leicester Road Anstey LE7 7AT 0116 236 3113 www.sportvision.co.uk
b	Geraint William Griffiths 2020 "The Comparative Rate of Reading Speed Test (CRST): The importance of Comparing the Rate of individual Character Recognition (Static Tracking Speed) in Serif and Non-Serif Fonts" EC Ophthalmology 11.8.(2020): 06-17

Appendix 4: Summary of the non-cycloplaegic routine binocular assessment and tests

Test	Method /Comment
History and symptoms	See history signs and symptoms from the initial screening on the subjects' record card
LogMAR Vision at high and low contrast	First as the child presents Then with specs if worn or previously prescribed
Cover test	With and without Distance and near any observable movement significant
Pupil size	Anisocoria? reduced reaction to light. Large pupils can be indicative of reduced accommodation.
Ocular motor balance	Objective 3m and 40cm (Von Graefe)
Hand foot dominance	Writing hand /Roll tennis ball for foot
Eye dominance	4 responses annotate ^{D} if drift
Eye tracking / Motility Eye speed/ tracking	Schoolvision formal eye track (one loss significant) Dynamic Fixation
CReST chart 1 or 2 Rate of character recognition	Comparative Rate of reading speed test as the child presents with and without own specs if brought
Refraction	Monocular, then Binocular refine with Humphris +0.75 blur Very careful check for astigmatism, Recheck spheres
Fixation Disparity	Distance Mallet then recheck spheres
The Eye Bright Test (EBT)	Colour preference and light sensitivity
Accommodation facility	+1.00 binocular add is it better or worse then increase by +0.50 steps
Near Fixation disparity	Freeman or Mallet (Recheck add) and recheck prism if more + is added. Confirm with Rice Test [6] at 40cm
Final refraction result and Visual Acuities	Record result and pupilliary distances, and dispensing details, one pair, two pairs, varifocals prism, coating index and tint details
Post refraction rate of character recognition CRST	Use EBT tints to screen for light sensitivity need for contrast or glare filters [7]
Dispensing	Handover to the dispensing assistant to measure CRST speeds with and without prescription. Chose frame(s)

Appendix 5: Diagnostic at risk criteria Hemyock 20.4.15

Condition/Test		At Risk Criteria		Units/Method
Diagnosed Dyslexia?		Yes		Ask
Spelling Good Average Week		Weak		Subjective
Writing good average weak		Weak		Subjective
Eye dominance		Left tendency		Hand over Hand
Existing spectacles? Dist, Near, Both		Yes, Which		Ask/Observe
Any problems?		Yes		History Symptoms
Retinoscopy	Distance	Myopia	> -0.25	Against movement
		Hyperopia	>+1.00	With movement

(Plus 1.50 Working distance)		Astigmatism	> -0.75	Plus, or Minus Cyl
Retinoscopy	Near	Lag	> +1.00	Observe forehead
LogMAR Vision High Contrast (90%)		R&L 100 Lux	> 0.2	LogMAR Units
LogMAR Vision Low Contrast (10%)		R&L 100 Lux	> 0.4	LogMAR Units
Objective Muscle Balance	Distance	Eso phoria	> 0	Prism dioptres
		Exo Phoria	> 0	Prism dioptres
	Near	Eso Phoria	> 1	Prism dioptres
		Exo phoria	> 2	Prism dioptres
Cover test	Distance	Eso phoria		Prism dioptres
(Quantify any observable Movement)		Exo Phoria		Prism dioptres
	Near	Eso Phoria		Prism dioptres
(Quantify any observable Movement)		Exo phoria		Prism dioptres
Schoolvision Motility		Fixation Losses	> 0	Count
Rice Test	Bead	Two beads		
	Strings	One string		Record
	Cross	Before or after		cms
	Clearer	R or L		Record
	Higher	R or L		Record
Dynamic Fixation (DFT)Tracking		Number Reversal		Record
1st Trial			> 20	Seconds
Completed trials			>45	
Trial		Incomplete		
Colour Pref and Light Sensitivity (EBT)		Strong		Record
(Strong, medium, mild?)		Likes blue dislikes yellow		Record
Reading speed (CRST)	Times	Speed	> 50	Seconds
	Gill Sans	Speed	> 45	Seconds
	Difference between Speeds		>10	Seconds
	Phonetic?	Yes (%?)		Record
Accommodation facility +1.00 Add?		Yes		Record
Ball catching @ 6m underarm		> 1 Miss		Record

Appendix 6

Resolvable behavioural traits observable in children with binocular or development deficiencies whilst CRST reading speed is measured [a, b].

Method

Reading speed is measured in two stages. First the time is recorded to read one line of 60 characters imbedded in the top paragraph (the 5th line down); this is the high contrast serif optotype (Times). Then the subject reads a second line in the bottom paragraph (5th line down) and the time is recorded; this is the low contrast teal colour non-serif optotype (Gill Sans).

In addition to recording the times any distinctive behavioural traits (clinically significant signs) should be noted, these might include:

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- Missing out characters
- Re-reading or loosing the place
- Head postures (eg head tilt or chin elevation)
- Heightened anxiety, excessive body movement
- Indications of tension in body language or breathing
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- Facial contortions
- Voice or body tremor
- Saying the characters phonetically
- Saying the characters phonetically for half the line
- Inability to read any or more than a few characters
- Test card held "too close," (closer that 10 cm)
- Test care held "too far" away (greater that 30 cm)
- Rapid fatiguing
- Big sigh when reading finished.

Appendix 6: References

a	Geraint Griffiths 2016 Hemyock Study 2016 published Association of Sport and Schoolvision Practitioners (ASvP) www.schoolvision.org.uk, available for down-load at SVUK Ltd 9 Leicester Road Anstey LE7 7AT 0116 236 3113
b	Geraint William Griffiths 2020 "The Comparative Rate of Reading Speed Test (CRST): The importance of Comparing the Rate of individual Character Recognition (Static Tracking Speed) in Serif and Non-Serif Fonts" EC Ophthalmology 11.8.(2020): 06-17

Appendix 7

Schoolvision screening questionnaire and data sheet (the results of the refraction were written on the back of the data sheet).

Name		
Age	Sports	Eye Colour

Dyslexia Diagnosed?	Spelling good/ average/weak	Writing good/ average/weak	Dominance Hand Eye	

Glasses Worn? √			Contact Lenses	Ever had an Eye Test?
Near	Far	Both	Soft/Hard	Date (approx.)

Any problems E.g. headaches, light sensitivity, difficulty reading

Data sheet		
Name		
1	2	
Retinoscopy Unaided, specs, contacts. (underline)	LogMAR Vision (as subject presents) Unaided, specs, contacts. (underline) Contrast 90% 10%	
R		
L		

3	4			
Muscle Balance	Eye Tracking			
Dist	Motility / Figure of 8	Dynamic Fixation (trials)		
Near		First	Second	Third

5			6	
Colour Preference (EBT) No Best Worst Preference √			Reading Speeds	
			Times Gill Sans	+1.00

7	8
Ball Catching 10 trials	Leg Standing (20 Seconds)
	Data inconclusive not included in final analysis

Appendix 8

The difference between Vision and Visual Acuity.

Visual acuity was an important consideration in this research particularly when measuring a subsequent improvement (due to more stable binocular vision or resolution of amblyopia).

In general practice and amongst new graduates the terms "Vision" and "VAs", are interchangeable. In a study where visual acuity is perhaps the most important outcome, the two terms should be clearly differentiated.

Visual acuity is the best vision in the trial frame on the day of the refraction, it is specified by date. Everything else is vision (V):

- Unaided V,
- V with new glasses,
- Distance V,
- Near V,
- V in contact lenses,
- V in old glasses,
- V in reading glasses,
- V in scratched glasses
- It is specified by the condition under which it is measured and the date.

Appendix 9a: Effect of spectacles on Times and Gill Sans CRST speeds at the time of testing

(i) **For the whole group** N = 56

	No Specs	With Specs	% Improve	p
Times (T)	50.36	43.08	16.9	2.36E-08
Gill Sans (G)	49.11	44.37	10.7	5.81E-05
P (T&G) the same	0.208	0.088		

(ii) Where there were **binocular vision difficulties** ("Times" speeds slower) N = 34

	No Specs	With Specs	% Improve	p
Times (T)	53.74	43.6	23.26	1.123E-07
Gill Sans (G)	47.94	44.57	7.56	0.01089
P (T&G) the same	1.793E-08	1.52E-01		

(iii) Where there were **developmental difficulties** ("Times" speeds faster) N = 22

	No Specs	With Specs	% Improve	p
Times (T)	45.14	42.27	6.79	0.0119
Gill Sans (G)	50.92	44.08	15.52	0.000799
p (T&G) the same	4.18E-06	0.0853		

Appendix 9b: Effect of spectacles on Times and Gill Sans CRST speeds at follow up

(i) Where there were **binocular vision difficulties** (“Times” speeds slower) N = 13 (39%)

	No Specs	With Specs	% Improve	p
Times (T)	49.89	42.59	17.14	1.12E-07
Gill Sans (G)	43.78	46.27	-5.38	0.01089
p (T&G) the same	6.49E-03	1.09E-01		

(ii) Where there were **developmental difficulties** (“Times” speeds faster) N = 20 (60.61%)

	No Specs	With Specs	% Improve	p
Times (T)	43.25	39.28	10.11	2.40E-02
Gill Sans (G)	49.5	42.7	15.93	0.004213378
P (T&G) the same	0.00070	0.01120		

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