The Standard of Vergence Eye Movements in Children with Reading Difficulties

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ABSTRACT

Children with reading difficulties frequently present with reduced vergence ability. This study investigated the visual status of 94 children aged 8 to 10 years old, 53 who read at the appropriate level for their age or better and 41 who read at least 6 months behind the level for their age.

The children were assessed using the GAP reading test, followed by a full orthoptic assessment that included visual acuity, cover test for near and 6 metres, ocular movements, accommodation, stereopsis, reference eye, hand and eye dominance as well as eight measures of vergence and the results were compared between the two groups using a two factor analysis of variance.

The results showed a small but significant reduction in fusional divergence in the reading difficulty group measured with the prism bar for near (p = .005) and distance (p = .024) and fusional convergence for distance (p = .030). The results also showed a significant difference for hand dominance (p = .038) with more left handed subjects in the reading difficulty group. There were no significant differences between the two groups on all other measures. Prism fusion range measurements for near and distance should be included in the routine orthoptic evaluation of children with reading difficulties.

Keywords: convergence, divergence, reading difficulty.

INTRODUCTION

Children with reading difficulties often complain of symptoms of eyestrain and frequently present clinically with reduced vergence ability[1,2]. Despite treatment to improve visual symptoms being given to many children with reading difficulties, there have been few controlled studies to ascertain if these children do have reduced visual standards compared to children in the same population who are reading at the level appropriate for their age. This study is using the bench mark that a child has reading difficulties if their reading ability is at least six months behind the standard reading level for their chronological age as assessed by the classroom teacher using the GAP reading test.

The purpose of this study is to determine whether there is any relationship between reading difficulties and clinical measures of vergence or the visual factors of visual acuity, cover test, ocular movements, accommodation, stereopsis, reference eye, hand and eye dominance.

Gender and Reading Difficulties

Studies of the effect of gender on reading difficulties have indicated a higher incidence in male subjects than female. This has ranged from 2:3 to 4:5, depending on the study[3]. However a population study of 5,718 children in Minnesota[4] found that boys were two to three times more likely to be affected than girls. Eden, Stein, Wood and Wood[5,6] consider that there are no significant differences for gender.

Comparative studies of visual defects between normal readers and children with reading difficulties.

The following studies have found no difference in ocular findings between the normal readers and those with reading difficulties. Of the 3,000 seven year old children screened in Bergen[7] 8% of the group were found to have dyslexia, but it was found that the ocular status was almost the same among the normal reading children and those with dyslexia. Helveston's study[8] assessed the visual function and academic performance of 1,910 children and found there was no relationship between the two. Visual acuity was normal (20/30 or better) in 94.2%, convergence near point was 10 cm or less in 98%.

A Melbourne study[9] by Kiely, Crewther and Crewther found no significant correlation between reading ability and the visual parameters of refractive error, amplitudes of accommodation, convergence near point and heterophoria. A Canadian study by Letourneau[10] also found there was no significant difference between children who showed convergence insufficiency and those who did not with regard to school results. Other studies have found some subtle differences between the two groups. In the USA a study by Benton[11] over seven years found that 22% of dyslexic children and 4% of good readers had a reduced convergence near point (more than 5 cm from the base of the nose). An extensive study in Finland (Latvala)[12] found that there was no significant difference between a group of 55 dyslexics and 50 normal readers for visual acuity, cycloplegic refraction, amount of heterophoria and heterotropia, stereoacuity, fusion or accommodation. However there was a significant difference (p= 0.0385) in the convergence near point between the two groups, when a convergence near point of 8 cm or worse was used to define reduced convergence.

Eden, Stein, Wood and Wood[5,6] using infrared oculography measured convergence and divergence on the Synoptophore and demonstrated that convergence was not significantly different between normal subjects and those who had a reading disability. However they found that there was a significant difference between the two groups when divergence was measured, this led to an assumption that binocular divergence was the best predictor of poor reading.

A similar study by Lennerstrand from Sweden[13] matched poor readers (low reading ability but normal or above normal cognitive capacity) with regard to class, age, sex, and cognitive capacity with normal readers from two separate age groups (Group A 8-9 year olds, Group B 11-12 year olds). There were 86 matched pairs in Group A and 40 matched pairs in Group B. This study found a significantly lower level of visual acuity in

the poor readers than normal readers of Group A, with 94% of controls with a distance visual acuity of 20/20 or better and only 83% of poor readers. For near acuity of 20/20 the control group had 99% and the poor readers 87%. Cover Test Near showed no significant difference between poor and normal readers, however they found that esophoria at near was more common in controls than dyslexics. The prism fusion range for convergence and divergence measured for near was not significantly different between normal and poor readers. However the fusion range on the Major Amblyoscope revealed a significant difference between the two groups in Group B, with the dyslexic group showing a slightly higher divergence range (p= 0.04).

Relationship between reading difficulties and reduced vergence ability

Atzmon[1] considered that some causes of reading disability were due to a lack of sufficient relative fusional vergence. Treatment to improve this function was given to 109 children. Following treatment 85% reported an improvement in one or more of reading, concentration, spelling, handwriting and copying from the blackboard. A further controlled study[14] was performed in which 31 pairs of children were matched for intelligence, grade in technical reading, grade in reading comprehension and mean convergence ability. One group was given conventional reading tutoring, and the other was given orthoptic treatment aimed at improving their convergence ability to the same level as the previous study. It was shown that orthoptic treatment to improve convergence amplitudes to 60[Δ] was as effective as conventional in-school reading tutoring treatment in improving reading standards.

Schor and Ciuffreda[2] consider that if the symptoms from convergence insufficiency are not treated they may have long term effects on educational development, career selection and attitude. If this is so, it is important to assess the vergence abilities of a controlled population of normal readers and subjects with reading difficulties to assess if there is a difference in their vergence abilities.

Hoyt states "To date, age-matched controlled studies with standard eye movement recordings are conspicuously few in the literature concerning eye movement abnormalities and the learning disabled child."[15]

The purpose of this study is to examine if there is a link between reading difficulties and different parameters of the vergence system. As this literature review has shown, the factors of gender, visual acuity, cover test 33 cm, cover test 6m, ocular movements, accommodation, stereopsis, reference eye, hand dominance, eye dominance and symptoms as predictors of reading difficulties differed greatly between the studies. As most of these functions form part of a full orthoptic assessment it was decided, for this study, to assess them in a normal reading group and a reading difficulty group to see how they compared with the published literature.

METHOD

A random sample of 94 children from a school population of 8 - 10 years old were tested for reading and visual status including ocular vergence skills. The vision assessment was performed within two weeks of the completion of a regular school based reading skill assessment (GAP reading test). The group consisted of 53 subjects with reading ability matched to chronological age or better and 41 subjects with reading ability at least 6 months behind the standard reading level for their age.

Clinical assessment

The following orthoptic assessment was carried out on each subject without the reading level being known by the examiner.

- Visual acuity using Logmar (csv-1000) acuity test at 8 feet.
- Visual acuity with each eye monocularly using the Moorfields near acuity chart and glasses if they were worn in the classroom.
- Cover tests for near and 6 meters (all subjects with orthophoria or heterophoria were included in the study).
- Smooth pursuit and saccadic eye movements.
- Accommodation and three consecutive measures of convergence using the RAF rule.
- Voluntary convergence.
- Fusional convergence and divergence using the prism bar for near and 6 metres.
- Fusional convergence and divergence on the Major Amblyoscope
- Reference eye[7]
- Stereopsis tested by the Titmus Four Dot test.
- The preferred hand used to write with
- Eye dominance

The data for each subject was entered into a Microsoft Excel computer program and analysed using the Statistical Package for the Social Sciences (SPSS) computer program (version 10.0 for Windows). The eight measures of vergence ability were analysed using two factor ANOVAs. The dependent measures of gender, reference eye, hand dominance, stereopsis and symptoms in relation to reading difficulty status were assessed with chi-square tests. Hand dominance was compared using the Fisher's Exact probability two-sided test. The significance level was set at 0.05.

RESULTS

There were 94 subjects tested who consisted of two groups, one who read at or above the level for their chronological age (n=53) and the other (n=41) who read at least six months behind their chronological age. This allowed for comparisons of visual function and vergence ability between the two groups. Visual acuity on the Logmar chart ranged from - 0.30 to 0.22 in each eye (which is the equivalent of 6/3 to 6/10 (-1) on the Snellen chart). Visual acuity for near was N5 for all subjects. The non vergence results are shown in Table 1.

Table 1. Non vergence results.

		Normal Reading (n=53)	Reading Difficulty (n= 41)	P values
Gender	Male 46	24 (45%)	22 (54%)	.450
	Female 48	29 (55%)	19 (46%)	
Cover Test Near	Orthophoria	49 (92.5%)	40 (97.5%)	
	Esophoria	0	0	
	Exophoria	4 (7.5%)	1 (2.5%)	
Cover Test 6m	Orthophoria	53 (100%)	41 (100%)	
	Esophoria	0	0	
	Exophoria	0	0	
Ocular Movements	Normal Pursuits	51 (96%)	41 (100%)	
	Abnormal pursuits	2(4%)	0	
	Normal Saccades	53 (100%)	41 (100%)	
	Abnormal Saccades	0	0	
Accommodation	Normal	52(98%)	39 (95%)	.444
	Abnormal	1 (2%)	2 (5%)	
Voluntary Convergence	With Vol. Conv.	38 (71.7%)	25 (61%)	.4846
	With no Vol.Conv.	13 (24.5%)	15 (36.5%)	
	Indeterminate Vol.Conv.	2 (3.8%)	1 (2.5%)	
Symptoms	Nil	48 (90.6%)	34 (82.9%)	.371
	Slight	5 (9.4%)	6 (14.6%)	
	Moderate	0	1(2.5%)	

There was no significant difference in results between the two groups for any of the visual tests in the above table. The eye and hand related results are shown in **Table 2.**

Table 2. Eye and Hand related results. Test

		Normal reading (n=53)	Reading difficulty (n=41)	P values
Reference Eye	Right Eye	27 (51%)	16 (39%)	1.475
	Left Eye	22 (41.5%)	20 (49%)	
	Unstable	4(7.5%)	5 (12%)	
Hand Dominance	Right Hand	49 (92.5%)	31 (75.6%)	.038
	Left Hand	4 (7.5%)	10 (24.4%)	
Crossed Dominance	Crossed	27 (50.9%)	15 (36.6%)	.165
	Uncrossed	26 (49.1%)	26 (63.4%)	
Eye Dominance	Right Eye	41(77.3%)	33 (80.5%)	1.000
	Left Eye	11 (20.7%)	8 (19.5%)	
	Unstable	1 (2%)	0	

P bold indicates a significant result.

The reference eye and hand dominance tests were compared to give the crossed or uncrossed dominance results. The hand dominance between the two groups was significant (p= .038, using the Fisher's Exact probability two sided test) with more left handers in the reading difficulty group. There was no significant difference for eye dominance or reference eye. The vergence and stereopsis results are shown in Table 3.

Table 3. Vergence and stereopsis results.

		Normal Reading Group		Reading Difficulty Group		P values
		Mean	S D	Mean	S D	
RAF rule conv	1st	5.5 cm	1.2	5.7 cm	1.2	.290
	2nd	5.5	1.2	5.9	1.4	.251
	3rd	5.7	1.5	5.9	1.5	.380
Prism Fusion Range Near	Conv	25	8.8	22.3	7.8	.165
	Div	10.2	2.3	8.9	1.9	.005
Prism Fusion Range Distance	Conv	9.0	2.5	7.9	2.2	.030
	Div	7.0	2.3	6.0	1.7	.024
Major Amblyo-scope	Angle	-.5 prism dioptres	1.1	-.4	.7	.526
	Conv (blur)	19.5	7.1	20.2	6.4	.599
	Conv. (break)	47.8	19.9	46.6	22.1	.795
	Div	10.5	2.1	10.1	1.4	.244
Stereopsis(Titmus)		71.5	116.2	53.9	31.1	.407
Vol Conv						.485

P bold indicates significant result.

A comparison of the vergence results between the two groups indicated that there was a small but significant difference on the measures of base in prism fusion range for near (p = .005) and far (p = .024). and base out prism fusion range (p = .030) for far. RAF rule convergence was measured three consecutive times and there was a significant difference (p = .024) of reducing convergence ability between the three measures in a linear relationship for the total population but no significant difference between the two groups.

DISCUSSION

These results confirm that there is no significant relationship between reading ability and reduced vergence or fusional amplitudes as measured with the RAF rule, prism bar convergence for near, the Major Amblyoscope or measures of voluntary convergence. There was also no significant difference in gender, visual acuity, cover test, accommodation, stereopsis, eye dominance or reference eye which could account for poor reading ability.

There was a significant difference (p = .038) between the two groups in hand dominance with more left handed subjects in the reading difficulty group. This finding is consistent with the previous study of Brown[16] who found the proportion of left handers was almost twice as high as the normal population. In the studies of Stein et al.[56] there was no significant difference in handedness between the normal readers and reading disabled groups. Left handedness has a higher incidence in subjects with reading difficulties.

The results that showed a statistical significance between the two groups in vergence ability were divergence measured with the Prism Bar for near and convergence and divergence measured with the Prism Bar for 6 metres. When the mean and standard deviation measurements for these are compared there is not a great deal of clinical difference, approximately one prism dioptre. This would indicate that clinically a difference between the two groups may not be noticed. This difference may be more demonstrable in a larger sample. The difference

in divergence ability between the two groups (as measured with the prism bar for near) was significant at p= .005 in the present study. Lennerstrand[13] found that the prism fusion range of divergence measured for near was not significantly different between normal and poor readers. The difference in convergence (p= .030) and divergence (p=.024) ability of the reading difficulty subjects was also significant compared to the normal readers when measured with a prism bar for 6 metres. Rarely are prism fusion ranges for six metres performed if the vergence mechanism is being assessed and therefore the results can only be compared to the study by Atzmon[14] when prism bar convergence for 6 metres was recorded but no significant difference was found between the two groups.

These findings may suggest that children with reading difficulties have a reduction in their ability to relax their convergence and/or may demonstrate a deficit in the divergence mechanism. The significant difference in divergence ability as measured with the prism bar suggests that these may be determining factors in children with reading difficulties. Most studies rely on Major Amblyoscope recordings for vergence for 6 metres, especially as it is easy and quick to perform vergence measures following the reference eye test. Atzmon[1] agrees that preference should be given to testing convergence amplitudes with loose prisms or a prism bar because prism vergences more closely resemble everyday seeing and avoid "instrument convergence" induced by the Major Amblyoscope.

Atzmon 1 has observed that children with poor convergence amplitudes at distance may have a reading problem despite good convergence at near, with their main problem difficulty copying from the blackboard, however they found no correlation between the near point of convergence and absolute convergence amplitudes measured for distance and near with a prism bar. This study recommended to the Minister of Education in Israel "all dyslectic children also be given an ophthalmologic and orthoptic evaluation, emphasising the testing of prism vergence amplitudes, and with special attention to asthenopic complaints."

CONCLUSION

Prism fusion measurements of convergence and divergence for near and 6 metres should be included in the routine ophthalmic and orthoptic evaluation of all children with reading difficulties. Comparing the results of the present study and others cited in the literature review there was no significant difference between the normal readers and reading difficulty groups for the factors of gender, visual acuity, cover test near, cover test distance, ocular movements, accommodation, stereopsis, reference eye, hand dominance, eye dominance, symptoms and some measures of vergence in the present study. This indicates that these are not significant factors in reading difficulty and reinforces the fact that all children with reading difficulties should have a full assessment and only visual anomalies that are found should be treated, however treatment of these anomalies may not lead to improved reading performance. There were significantly more left handers in the reading difficulty group, confirming other studies that this is a related factor for children with reading difficulties.

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