Chapter 6
Vision and Visual Acuity Data

6.1 Baseline Chart Scores

6.1.1 Unaided Vision

The initial chart scores for unaided vision are shown in table 6.1.1. All charts except Pelli-Robson are scored using CLAT converted logMAR units (see section 5.3 for an explanation of the scoring systems). The PR is scored in log units of contrast.

chart	*mean ± stdev (n=25)*	*range*
HCBL R	0.36 ± 0.31	-0.24 to 0.76
HCBL L	0.35 ± 0.32	-0.38 to 0.8
HCBL B	0.48 ± 0.33	-0.22 to 0.96
CLAT R	0.46 ± 0.30	-0.027 to 0.975
CLAT L	0.43 ± 0.46	-1.12 to 0.975
CLAT B	0.59 ± 0.33	-0.05 to 1.05
SO R	0.47 ± 0.39	-0.28 to 1.05
SO L	0.48 ± 0.29	-0.4 to 1.125
SO B	0.63 ± 0.36	-0.155 to 1.2
RRL R	0.58 ± 0.27	-0.13 to 0.975
RRL L	0.56 ± 0.28	-0.08 to 0.975
RRL B	0.68 ± 0.30	-0.13 to 1.15
LCBL R	0.10 ± 0.32	-0.43 to 0.7
LCBL L	0.13 ± 0.36	-0.65 to 0.68
LCBL B	0.23 ± 0.38	-0.35 to 0.84
PR R	1.59 ± 0.23	1.05 to 1.9
PR L	1.58 ± 0.31	0.6 to 2.05
PR B	1.81 ± 0.2	1.2 to 2.1

Table 6.1.1 Mean unaided vision scores.

The right eye and binocular results for all charts except PR are plotted on figure 6.1.1. It can be seen that the high contrast Bailey-Lovie chart scored the lowest and the Regan repeat letter chart the highest of the high contrast charts for unaided vision. This difference is not significant (ANOVA, p=0.07). The difference between the LCBL scores and those of all the high contrast charts was significant (p=0.05). The standard deviation across the group for all charts is about 3 lines indicating the spread of refractive errors present in the group. The mean scores for right do not differ from that for the left eyes by more than 0.03 units (1.5 letters on Bailey Lovie chart). The binocular scores were 0.1 to 0.15 log units (1 to 1.5 lines) higher than the monocular scores.

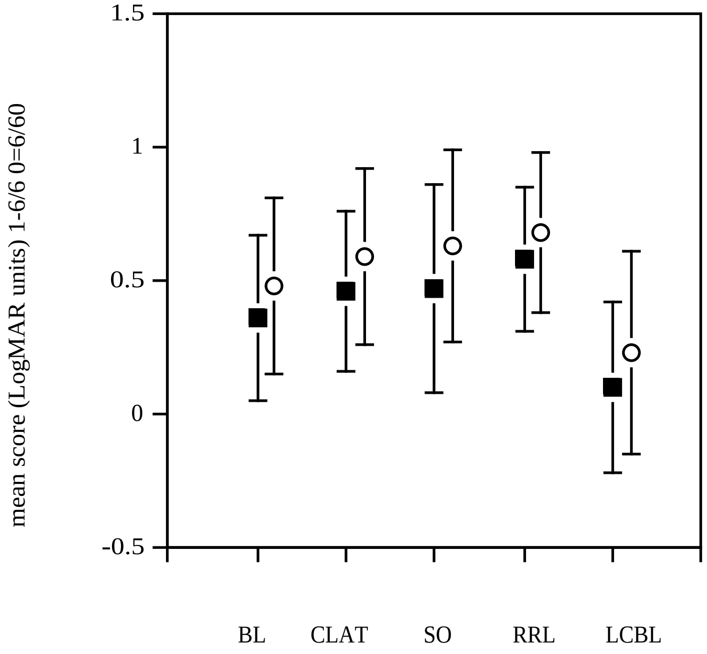

Figure 6.1.1 Mean unaided vision scores for the right eyes (filled squares) and binocular viewing (unfilled circles). Results for BL, CLAT, SO, RRL and LCBL are shown.

6.1.2 Corrected Acuity

The chart scores for corrected visual acuity are shown in table 6.1.2.

chart	*mean ± stdev*	*range*
HCBL R	1.10 ± 0.08	0.9 to 1.24
HCBL L	1.08 ± 0.11	0.72 to 1.24
HCBL B	1.15 ± 0.06	1.04 to 1.24
CLAT R	1.19 ± 0.07	1.025 to 1.3
CLAT L	1.17 ± 0.09	0.9 to 1.3
CLAT B	1.22 ± 0.08	1.1 to 1.325
SO R	1.23 ± 0.10	0.95 to 1.325
SO L	1.23 ± 0.11	0.95 to 1.4

SO B	1.29 ± 0.08	1.025 to 1.425
RRL R	1.20 ± 0.09	0.95 to 1.35
RRL L	1.18 ± 0.11	0.925 to 1.375
RRL B	1.24 ± 0.09	0.925 to 1.375
LCBL R	0.96 ± 0.10	0.72 to 1.14
LCBL L	0.92 ± 0.12	0.64 to 1.2
LCBL B	1.0 ± 0.10	0.8 to 1.18
PR R	1.82 ± 0.25	0.75 to 2.1
PR L	1.87 ± 0.15	1.55 to 2.1
PR B	2.02 ± 0.11	1.7 to 2.1

Table 6.1.2 Mean corrected acuity scores.

The right eye and binocular results for all charts except PR are plotted on figure 6.1.2. The standard deviations are about 0.1 log unit (about one line) across the group and the biggest difference between the mean score for right and left eyes was 0.04 units (low contrast Bailey-Lovie chart). For all charts the mean binocular score was about 0.06 better than the mean monocular score (approx. half a line). See section 6.4 for a comparison of monocular and binocular scores. The differences in mean scores between LCBL and the other charts are significant (p=0.05). The High Contrast Bailey Lovie chart scored significantly lower than the other high contrast charts by the following amounts: RRL 0.1 (p=0.05), CLAT 0.09 (p=0.05), SO 0.14 (p=0.05).

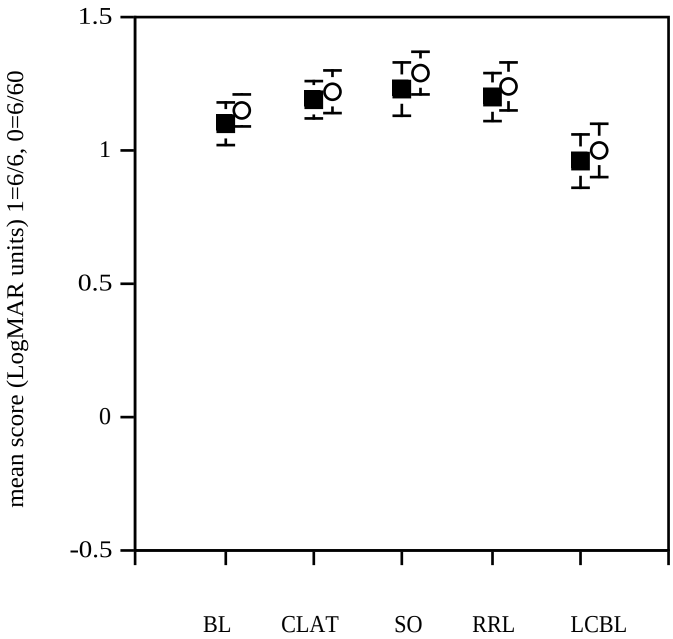

Figure 6.1.2 Mean corrected acuity scores for the right eyes (unfilled) and binocular viewing (filled). Results for BL, CLAT, SO, RRL and LCBL are shown.

6.1.3 Discussion

Comparing figure 6.1.1 and figure 6.1.2 it can be seen that the standard deviations for the mean scores are much larger for unaided vision than for corrected acuity. This reflects the range of refractive errors and hence the spread of vision in the sample. Refractive correction reduced this spread.

From observing these figures there also appears to be a greater difference between binocular and monocular scores for unaided vision. This difference, however is not significant. See section 6.4.

The low contrast chart scored significantly lower than the high contrast charts in each viewing situation. This would be expected due to the greater difficulty of the low contrast task.

Since all the charts do not give the same scores the angular size of letters is not the only factor in determining chart acuity. Among the other factors are contrast and the proximity of other letters. For both corrected and uncorrected scores the HCBL gives the lowest values of the high contrast charts although this result is only significant for the corrected scores.

6.2 Comparing Charts

In order to investigate the effect of crowding the difference between the high contrast Bailey-Lovie and the single optotypes was calculated. The Bailey-Lovie chart (see section 5.2.1) is designed to have constant crowding over all letter sizes and single optotypes have no crowding effect as there are no surrounding letters or contours.

In order to assess the role of unsteady fixation the difference between the high contrast Bailey-Lovie chart and the Regan repeat letter chart was calculated (see section 5.2.2 for a description of RRL chart).

In order to investigate the contrast dependency of the scores the difference between the low and high contrast Bailey-Lovie charts was calculated. In all cases this was done for monocular and binocular scores in both the corrected and uncorrected situations.

6.2.1 Chart Comparisons for Unaided Vision Scores

Table 6.2.1 shows the difference in unaided vision scores for the selected chart pairs.

	mean difference ± stdev R&L n=50	*mean difference ± stdev B n=25*
BL-RRL	-0.21 ± 0.13	-0.2 ± 0.14
BL-SO	-0.11 ± 0.16	-0.15 ± 0.15
BL-LCBL	0.34 ± 0.48	0.36 ± 0.54

Table 6.2.1 Mean chart comparisons for unaided vision scores.

The large standard deviation for the comparison including the low contrast chart is due to the effect of blur on low contrast scores introducing more variability.

6.2.2 Chart Comparisons for Corrected Acuity

Table 6.2.2 shows the difference in corrected acuity scores for selected chart pairs.

	mean difference ± stdev R&L n=50	*mean difference ± stdev B n=25*
BL-RRL	-0.07 ± 0.17	-0.07 ± 0.16
BL-SO	-0.12 ± 0.18	-0.11 ± 0.15
BL-LCBL	0.19 ± 0.17	0.16 ± 0.16

Table 6.2.2 Mean chart comparisons for corrected acuity scores.

In order to determine if there was any difference between the corrected and uncorrected situations with respect to crowding, eye movements and the ability to perceive low contrast the differences tabled above were compared in the two situations. The results for the corrected and uncorrected situations are shown on figure 6.2.3.

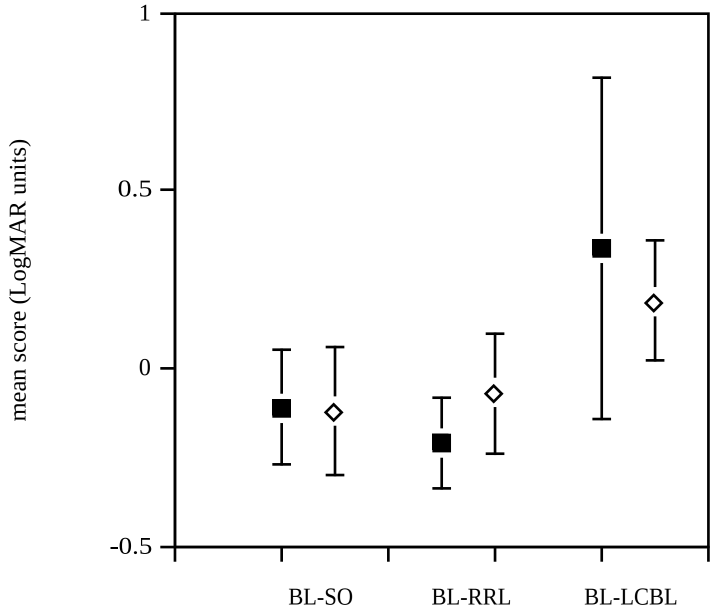

Figure 6.2.3 The mean difference across all subjects between chart pairs as labelled. The filled squares show the scores for unaided vision and the open diamonds those for corrected VA.

The difference between the corrected and uncorrected situation with regard to eye movements (that is the difference between the RRL and BL) was significant (p=0.0001). The difference between crowding on the Bailey-Lovie chart (BL-SO) in the situations of corrected acuity and uncorrected vision was not significant. The difference between groups in the change of score when reading a low contrast chart (BL-LCBL) was (although marginal) significant (p=0.044).

6.2.3 Discussion

i) The binocular differences were of a similar magnitude to the monocular differences for both corrected and uncorrected comparisons. In both situations (with and without correction) the SO scored on average about one line better than the BL chart. The difference in task difficulty between the SO and the BL chart (postulated to be due to the crowding effect) was not altered by the removal of the correcting lenses.This suggests that the effect of crowding is the same in the corrected and uncorrected situations.

ii)The RRL chart scored about 2 lines better than the BL chart for the uncorrected situation and only 2-3 letters more for the corrected situation. This difference is significant (p=0.0001). This result means that the relative difficulty of the two charts is different when correcting lenses are removed with the RRL chart becoming relatively easier. The RRL chart was designed to measure acuity independent of abnormal eye movements i.e. if fixation is unsteady a high score can still be achieved. This result suggests a difference in the quality of fixation between the corrected and the uncorrected myope.

Possible explanations for this result are: (1) that corrected chart acuity is limited by cone spacing and so any differences brought about by subtleties in visual style will be masked i.e. the eye movements in the corrected and uncorrected situations are the same but there is not an increase in score for the RRL in the corrected case because the acuity is already limited by other factors. (2) that eye movements are different with a minus refractive correction and contain less fixational movements than uncorrected myopic vision.

If the image minification of minus lenses is taken into account then the eye movements needed to move from fixating one point to another will be smaller. This may have an effect on fixational eye movements and points to the 2nd explanation as being correct.

During one study it was noted that subjects often reported scanning the edges or perimeter of the letters to help in recognition (Bradley et al, 1991). This also suggests a link between eye movements and acuity and can be compared to the shifting exercise (see section 3.2.1).

iii) The BL chart scored about 3.5 lines higher than the LCBL for uncorrected vision as compared with nearly 2 lines better for the corrected situation. This difference is significant ($p=0.044$). This suggests that the ability to perceive low contrast targets is relatively easier in the corrected situation, that is, the presence of blur lowers the threshold for low contrast acuity.

It is also of note that there is a large standard deviation for the uncorrected situation. This suggests that knowing someone's high contrast acuity does not mean that the low contrast acuity can be easily predicted.

6.3 Range of Chart Scores for a Refractive Error Range

6.3.1 Score Ranges

To establish the range of scores found for a given refractive error, the mean vision scores for refractive error groupings were found. The ranges were defined as shown in table 6.3.1.

range (D)	0 -1	-1 -2	-2 -3	-3 -4	-4 -5	-5 -6	-6 -7	-7 -8
n	2	17	7	5	4	3	6	2

Table 6.3.1 Refractive error ranges used and the number of subjects (n) in each grouping.

The results for all charts except the PR are shown on figure 6.3.1.

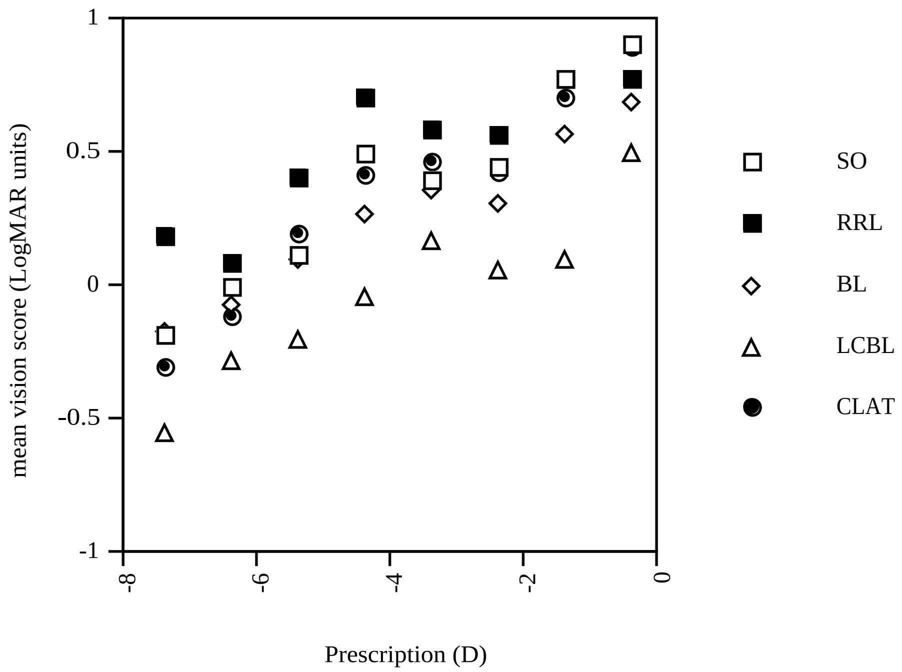

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Figure 6.3.1 The mean vision scores for a range of refractive errors is shown.

The results for each chart separately with error bars showing the standard deviations and a linear fit are plotted on figures 6.3.2-7. In figure 6.3.2 is shown the relationship between the BL vision score as a function of the non-cycloplegic refractive status of the subjects. A linear regression analysis (see line) shows that the vision score decreases with increasing refractive error (p=0.0001, r=0.98). Figures 6.3.3-7 show the same for the other charts. The results of the regression analysis for each were as follows:

chart	slope (chart dif. for 1D change)	y-intercept (predicted emmetropic score)	p	r
BL	0.12	0.73	0.0001	0.98
CLAT	0.14	0.93	0.0001	0.97
SO	0.16	0.98	0.0001	0.98
RRL	0.09	0.88	0.0040	0.88
LCBL	0.12	0.46	0.0005	0.94
PR	0.10	1.87	0.0025	0.90

Table 6.3.2 Slopes, y-intercepts p and r values from graphs 6.32-6.37.

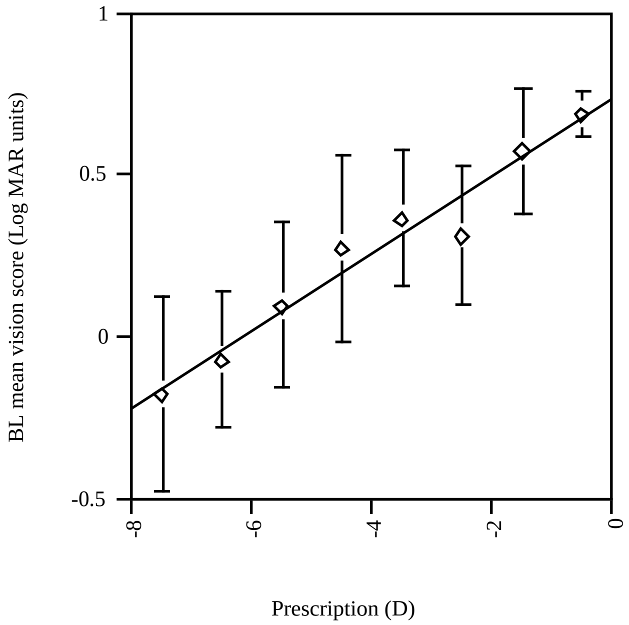

Figure 6.3.2 Mean scores for the BL chart for refractive error groupings (see table 6.3.1). The equation of the line is y=0.12x + 0.73, R=0.98, p=0.0001.

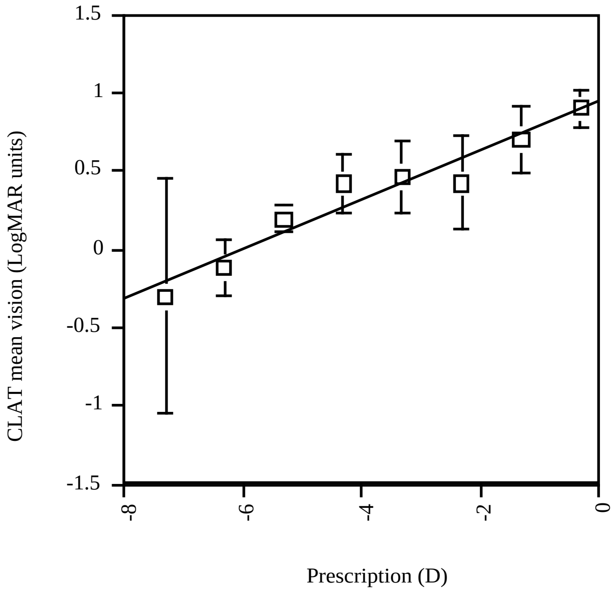

Figure 6.3.3 Mean scores for the CLAT chart for refractive error groupings (see table 6.3.1). The equation of the straight line is y=0.143x + 0.933, R=0.968, p=0.0001.

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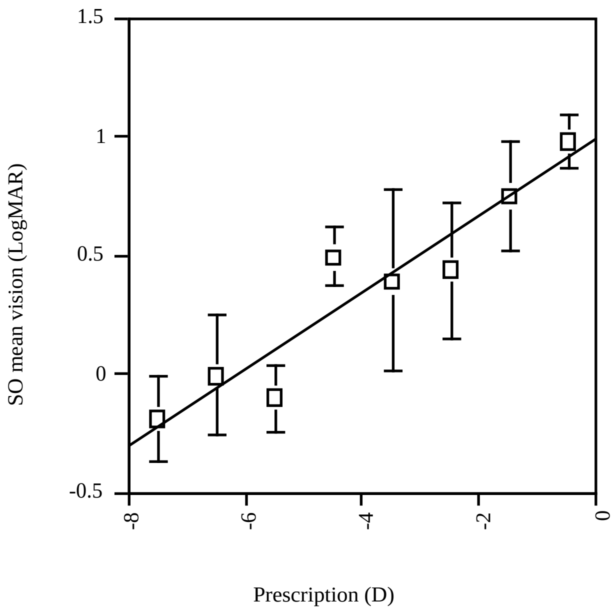

Figure 6.3.4 Mean scores for the SO chart for refractive error groupings (see table 6.3.1). The equation of the straight line is y=0.16x + 0.98, R=0.984, p=0.0001.

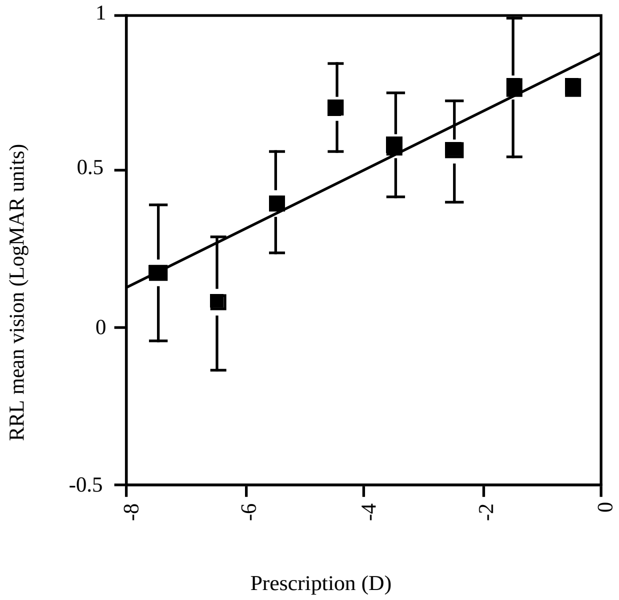

Figure 6.3.5 Mean scores for the RRL chart for refractive error groupings (see table 6.3.1). The equation of the straight line is y=0.094x + 0.88, R=0.878, p=0.004.

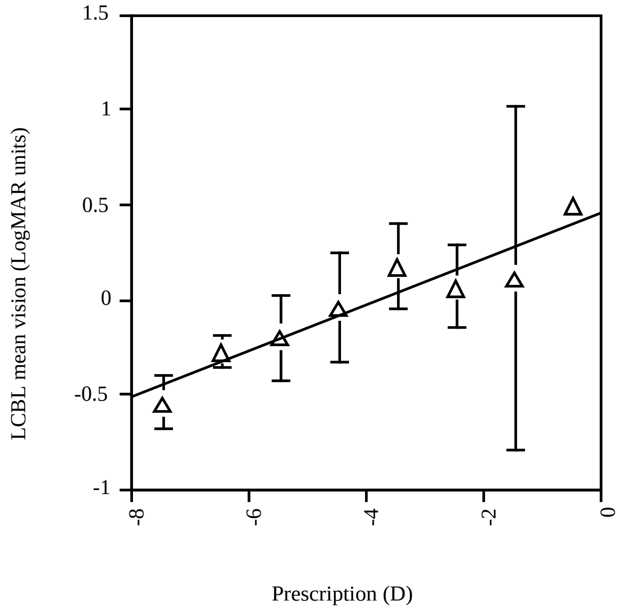

Figure 6.3.6 Mean scores for the LCBL chart for refractive error groupings (see table 6.3.1). The equation of the straight line is y=0.122x + 0.46, R=0.941, p=0.0005.

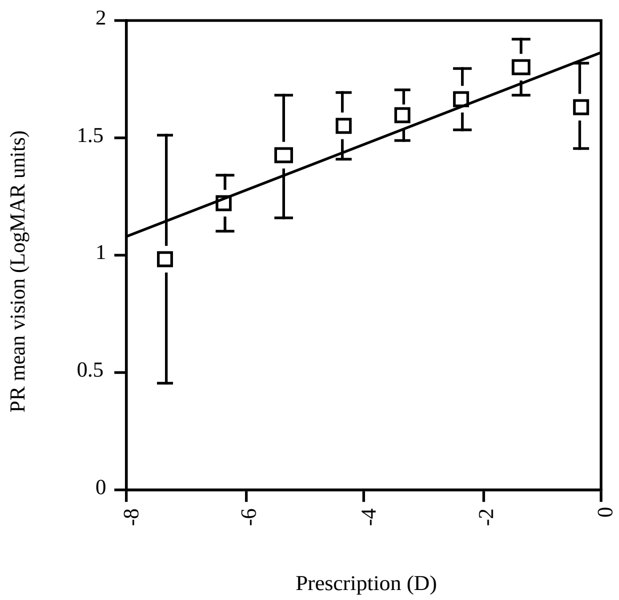

Figure 6.3.7 Mean scores for the PR chart for refractive error groupings (see table 6.3.1). The equation of the straight line is y=0.10x + 1.87, R=0.898, p=0.0025.

6.3.2 Discussion

The linear correlations on figures 6.3.2 to 6.3.7 can be used to calculate how much of a change in chart performance would be expected for a 1D change in refractive error. These can be seen on table 6.3.2. There are, however, standard deviations associated with these values which will mean that although a good guide, an individual's score will not be accurately predictable from the refractive error.

If the linear extrapolations of these graphs are used to predict the score for a refractive error of 0, that is emmetropic vision, the results shown on table 6.3.2 are found. These are not accurate since emmetropic scores on the high contrast charts would be expected to be at least 1.0 and the low contrast score 0.8. The BL and RRL scores seem particularly low when analysed in this way suggesting that something more than straightforward blur is limiting myopic vision for these charts.

6.4 Comparing Binocular with Monocular Scores

6.4.1 Binocular and Monocular Scores

For all charts and for the corrected and uncorrected conditions the means of the best monocular and binocular scores were compared. For each subject the best monocular score was subtracted from the binocular score. The mean across all subjects was then found.

chart	*binoc score mean±stdev*	*best monoc score mean±stdev*	*binoc-monoc mean±stdev*
Vis SO	0.63±0.36	0.56±0.36	0.07±0.14
Vis CLAT	0.59±0.33	0.54±0.31	0.05±0.11
Vis RRL	0.68±0.3	0.62±0.28	0.06±0.1
Vis BL	0.48±0.33	0.41±0.32	0.07±0.18
Vis LCBL	0.12±0.62	0.10±0.57	0.02±0.17
Vis PR	1.81±0.21	1.66±0.24	0.15±0.08

Table 6.4.1 Comparison of binocular and monocular unaided vision scores.

chart	*binoc score mean±stdev*	*best monoc score mean±stdev*	*binoc-monoc mean±stdev*
VA SO	1.29±0.08	1.26±0.10	0.02±0.05
VA CLAT	1.22±0.08	1.21±0.07	0.01±0.05
VA RRL	1.24±0.09	1.22±0.10	0.03±0.04
VA BL	1.18±0.14	1.15±0.16	0.03±0.06
VA LCBL	1.04±0.15	0.95±0.25	0.04±0.09
VA PR	2.02±0.11	1.9±0.11	0.13±0.11

Table 6.4.2 Comparison of binocular and monocular corrected acuity scores.

The binocular scores show relatively more improvement for the uncorrected condition with the exception of the low contrast Bailey-Lovie chart. This result is not significant (ANOVA, p=6). The biggest difference was for the single optotype and Bailey-Lovie uncorrected, the difference being 0.07. See section 9.1.2 for a discussion of these results.

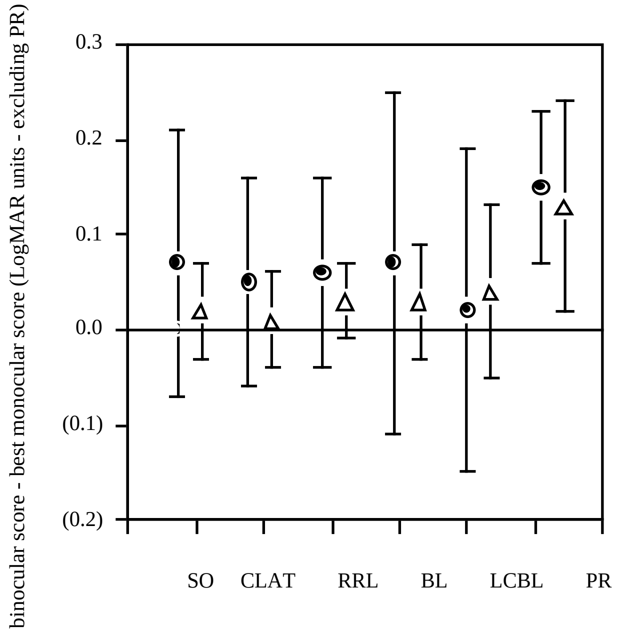

Figure 6.4.1 Mean over all subjects of binocular score minus the best monocular score for each chart. The filled circles represent unaided vision and the open triangles corrected acuity.

6.4.2 Discussion

These results show there to be a trend for binocular viewing to be a greater advantage in the uncorrected situation. This result is not significant, but this is possibly due to the large standard deviations in the uncorrected situation. Two possible explanations for a possible difference are: 1) in the corrected situation monocular acuity is already at threshold and so binocular viewing can not greatly increase the score, 2) in the uncorrected situation binocular viewing allows a greater freedom of neural interpretation and coordination of eye movements which can increase the score. This would also account for the larger standard deviation in the uncorrected case.

6.5 Pre and Post Therapy Chart Scores

chart	*Group A (n=6) mean±stdev*	*Group B (n=5) mean±stdev*	*Group C (n=6) mean±stdev*
HCBL R	0.07±0.13	0.04±0.26	0.06±0.16
HCBL L	0.02±0.09	-0.08±0.15	-0.04±0.14
CLAT R	0.10±0.17	0.02±0.17	0.02±0.22
CLAT L	0.07±0.15	-0.05±0.17	0.06±0.18
SO R	0.1±0.1	0.12±0.16	0.01±0.22

SO L	-0.04±0.06	0.05±0.14	0.09±0.13
RRL R	0.03±0.36	0.04±0.19	0.16±0.40
RRL L	0.09±0.11	0.13±0.18	0.17±0.33
LCBL R	0.05±0.13	-0.03±0.13	-0.06±0.08
LCBL L	-0.08±0.27	-0.12±0.24	-0.02±0.15
PR R	0.09±0.20	-0.07±0.30	0.04±0.15
PR L	0.13±0.15	-0.09±0.15	0.01±0.17

Table 6.5.1 Mean difference between monocular chart scores at t1 and t2.

For each chart there is no significant difference between the groups A, B and C at t1 and t2. (E.g a t-test on goup A for the before and after result on the BL chart gave p=0.8.) This indicates that the therapy groups did not score significantly higher than the control group on any of the charts after the therapy period.

The results for each chart are plotted in figures 6.5.1-6 showing the difference against the mean. These graphs show no obvious trends.

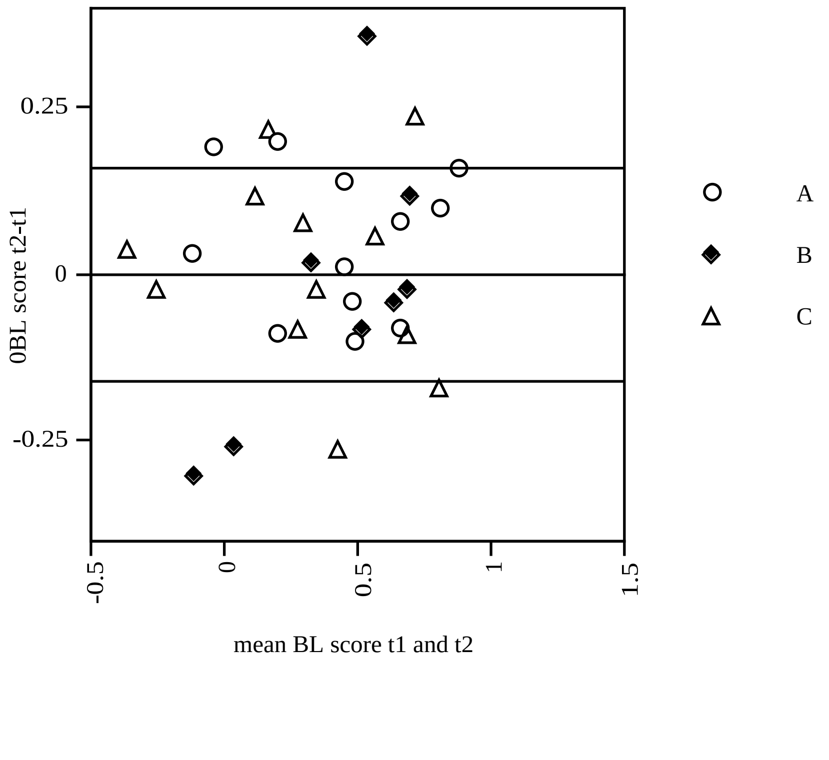

Figure 6.5.1 Difference of scores for BL chart at t1 and t2 plotted against the mean of the same for all groups.

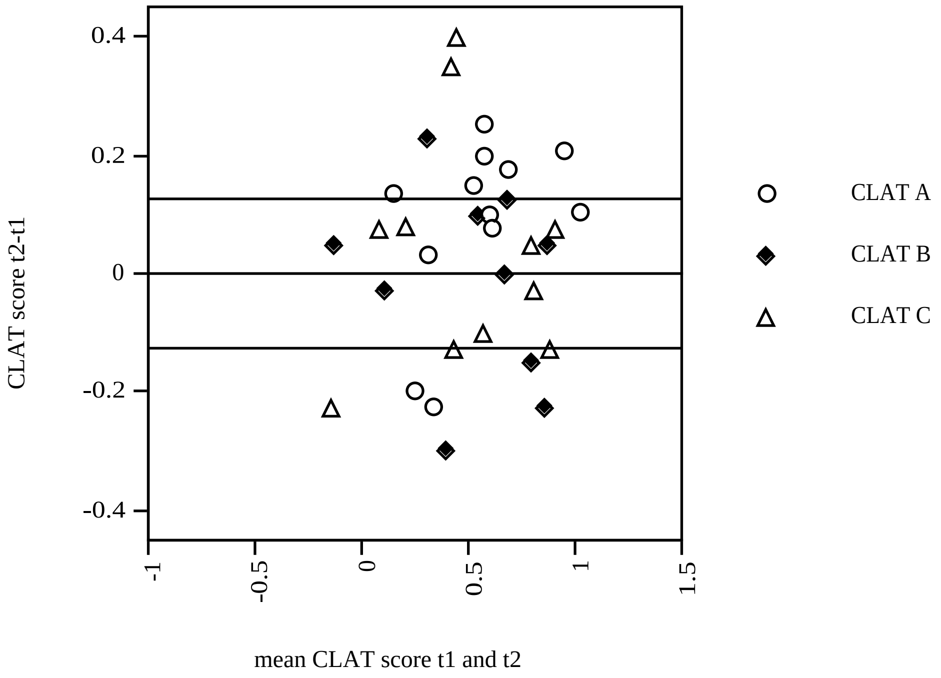

Figure 6.5.2 Difference of scores for CLAT chart at t1 and t2 plotted against the mean of the same for all groups.

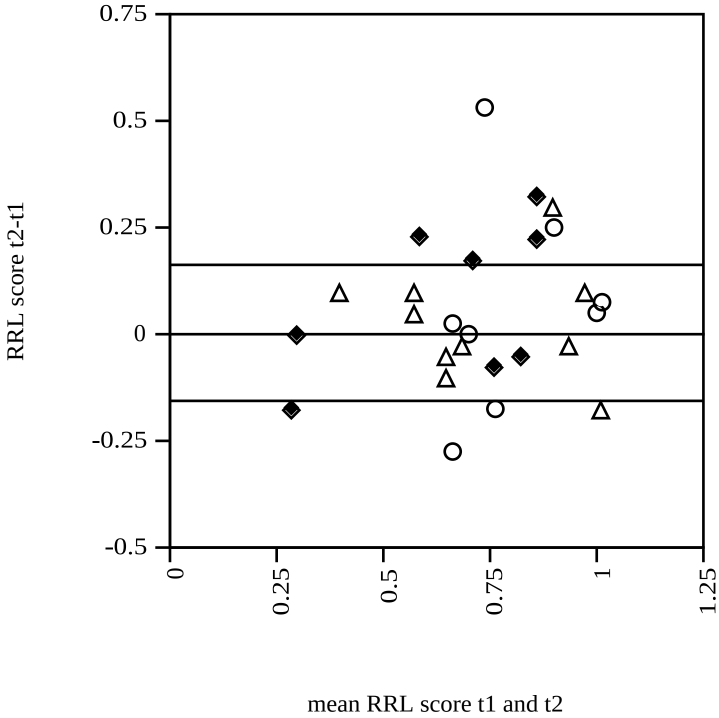

Figure 6.5.3 Difference of scores for RRL chart at t1 and t2 plotted against the mean of the same for all groups.

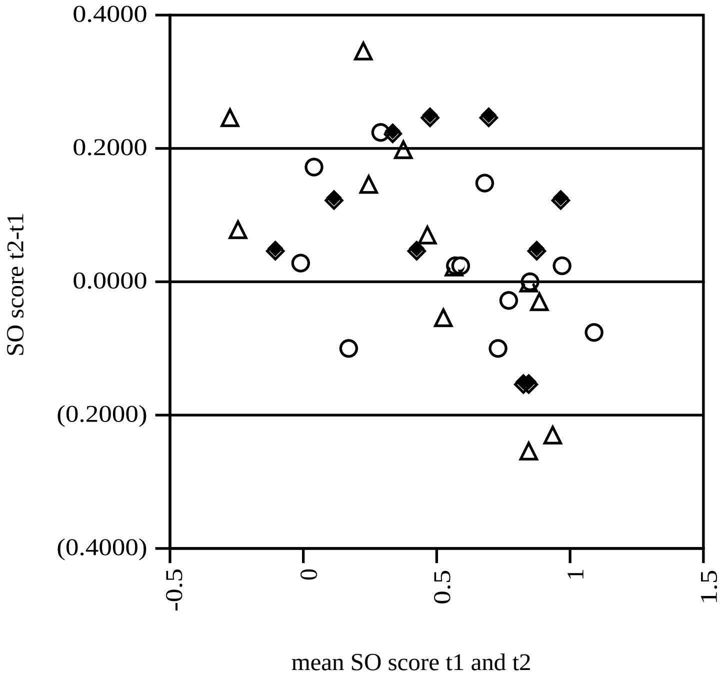

Figure 6.5.4 Difference of scores for SO chart at t1 and t2 plotted against the mean of the same for all groups.

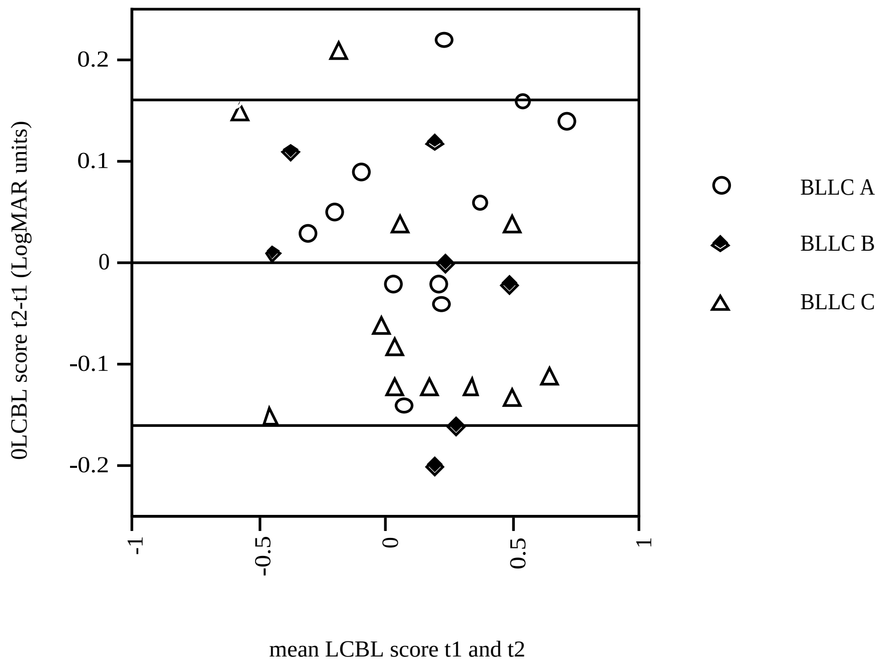

Figure 6.5.5 Difference of scores for LCBL chart at t1 and t2 plotted against the mean of the same for all groups.

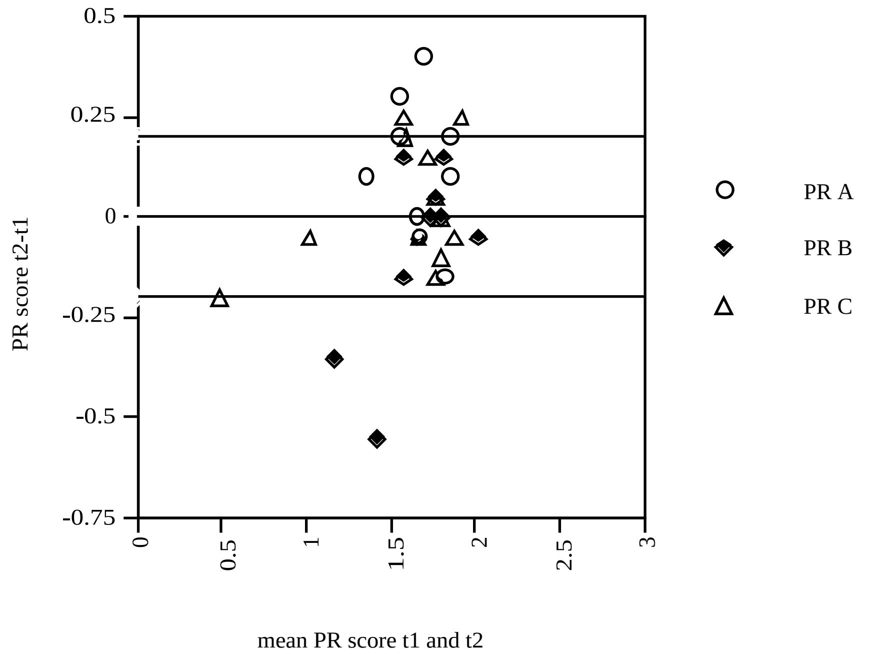

Figure 6.5.6 Difference of scores for PR chart at t1 and t2 plotted against the mean of the same for all groups.

6.5.2 Binocular Results

	Group A(n=6) mean±stdev t2-t1	*Group B (n=5)*	*Group C (n=6)*
HCBL B	-0.01±0.07	0.04±0.10	0.03±0.14
CLAT B	0.16±0.14	0.05±0.07	0.01±0.22
SO B	0.05±0.18	0.11±0.12	0.01±0.11
RRL B	0.02±0.17	0.05±0.05	0.07±0.16
LCBL B	0.02±0.11	-0.04±0.11	0.09±0.15
PR B	0.04±0.11	-0.03±0.22	0.07±0.10

Table 6.5.2 Mean difference between binocular chart scores at t1 and t2.

With the exception of HCBL (Group A) there was an improvement in the binocular score of all groups on all high contrast charts.

There was no change or a decrease in score for all the groups on the low contrast charts except for the PR for group A and the LCBL for group C.

These results are plotted on figure 6.5.7-12.

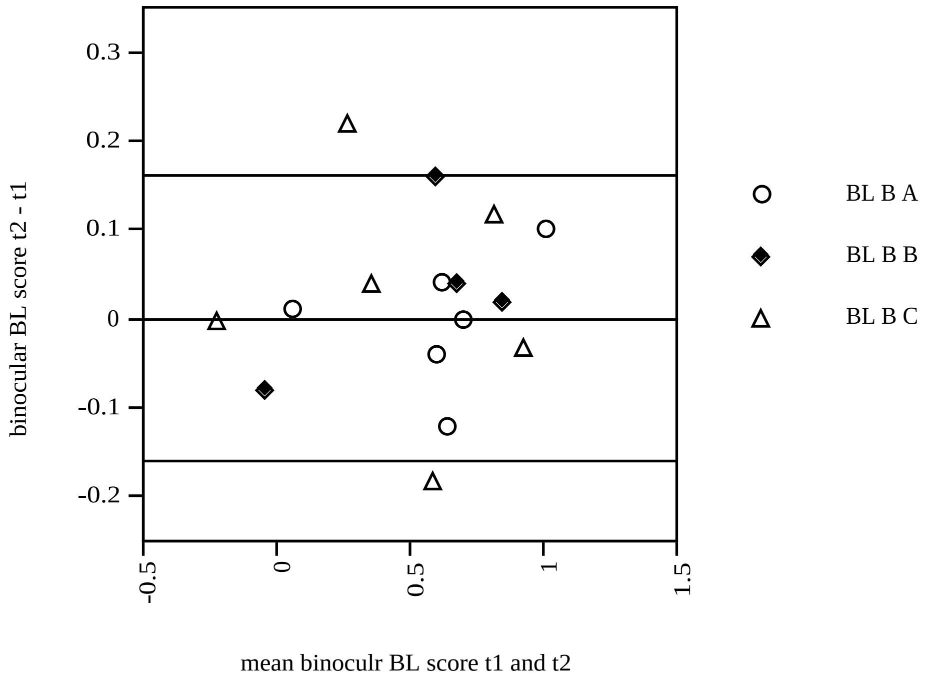

Figure 6.5.7 Difference of binocular scores for BL chart at t1 and t2 plotted against the mean of the same for all groups.

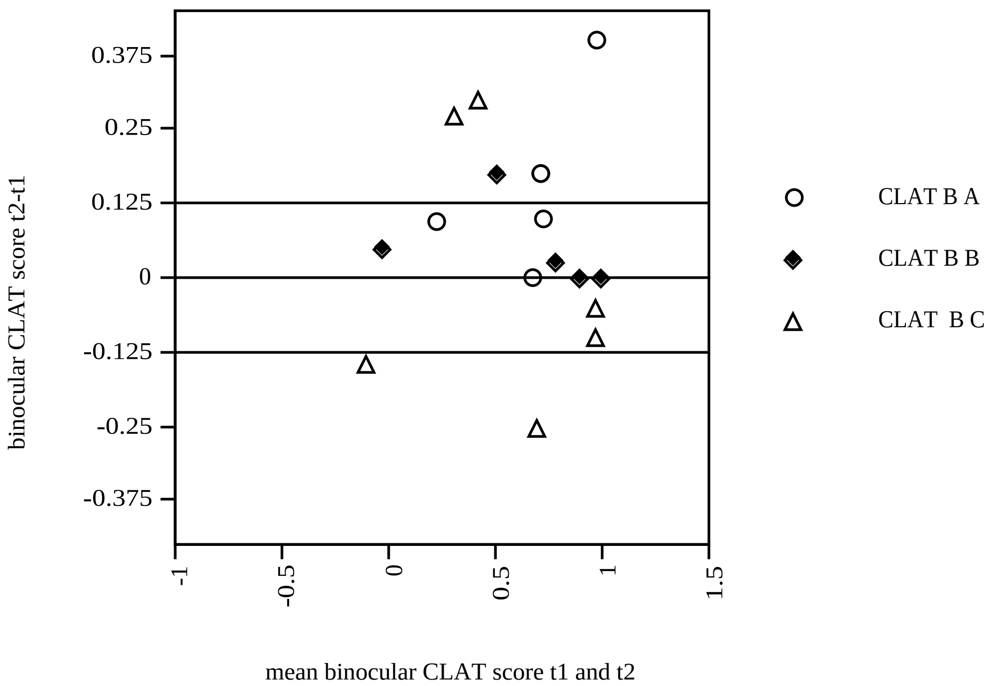

Figure 6.5.8 Difference of binocular scores for CLAT chart at t1 and t2 plotted against the mean of the same for all groups.

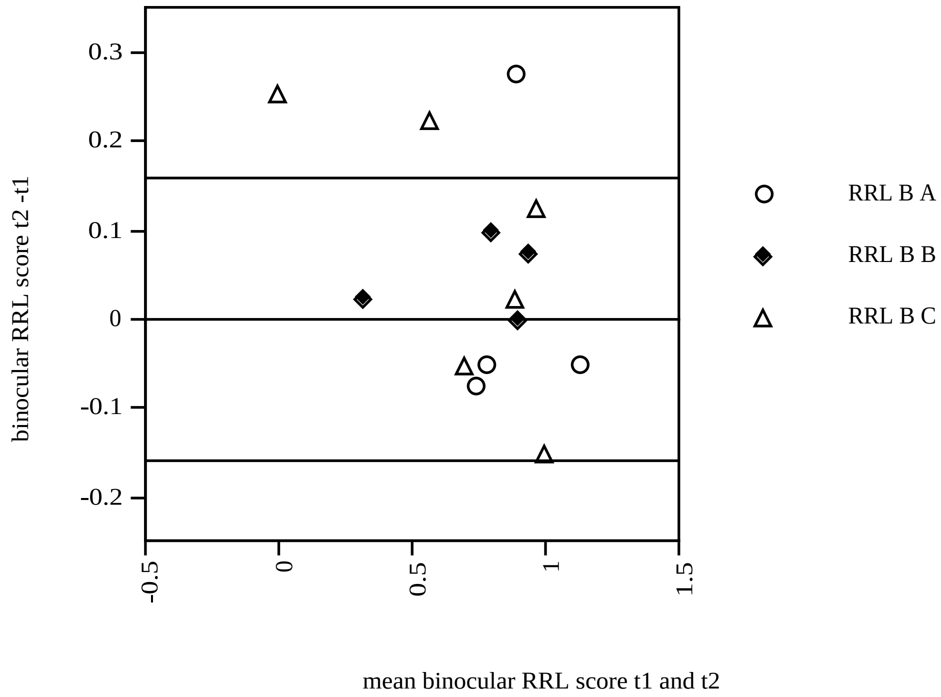

Figure 6.5.9 Difference of binocular scores for RRL chart at t1 and t2 plotted against the mean of the same for all groups.

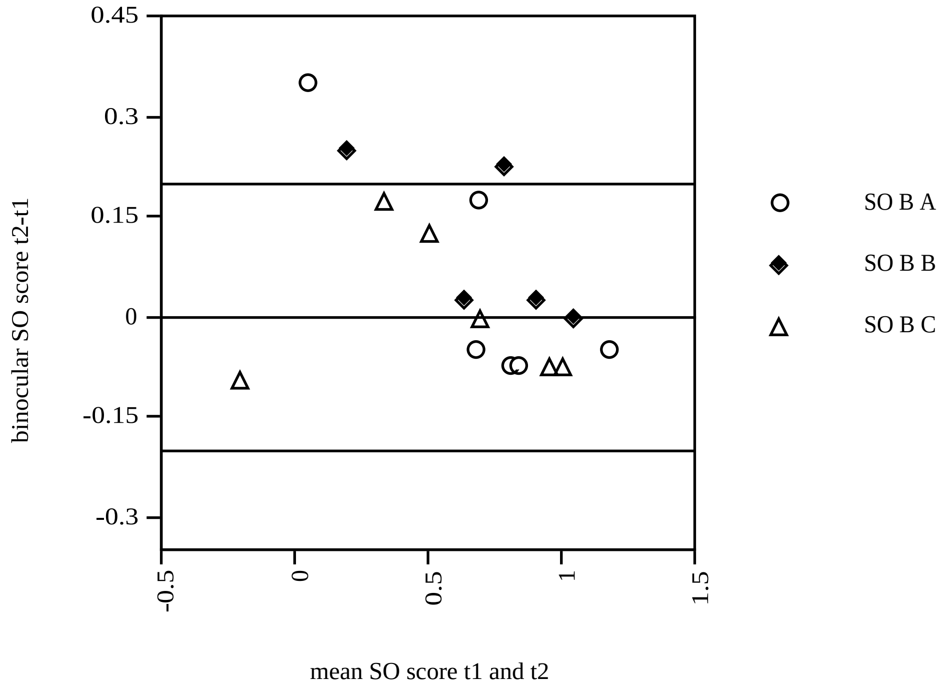

Figure 6.5.10 Difference of binocular scores for SO chart at t1 and t2 plotted against the mean of the same for all groups.

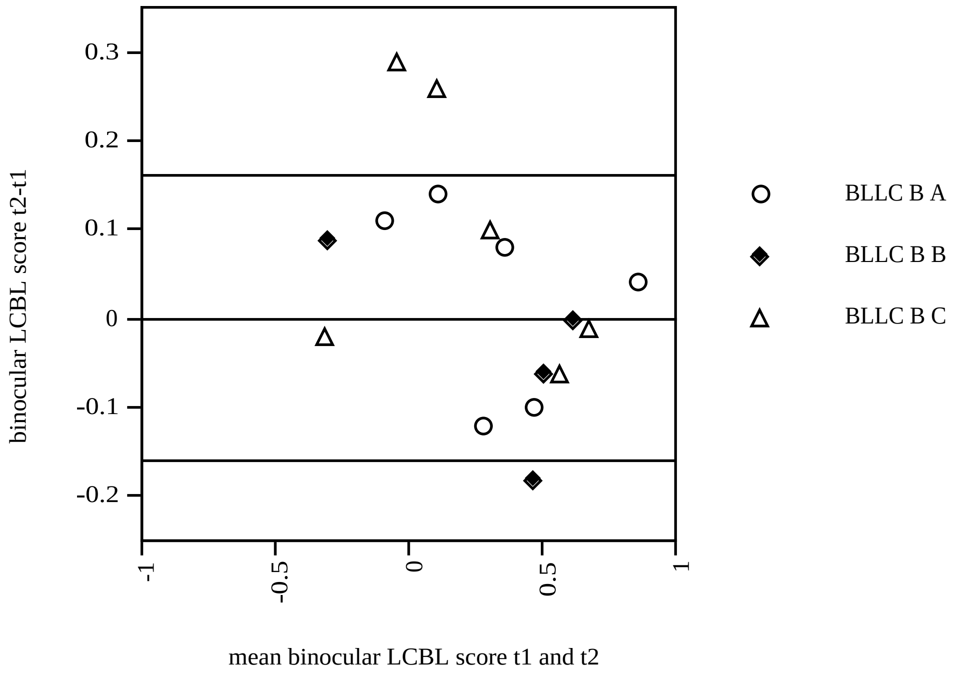

Figure 6.5.11 Difference of binocular scores for LCBL chart at t1 and t2 plotted against the mean of the same for all groups.

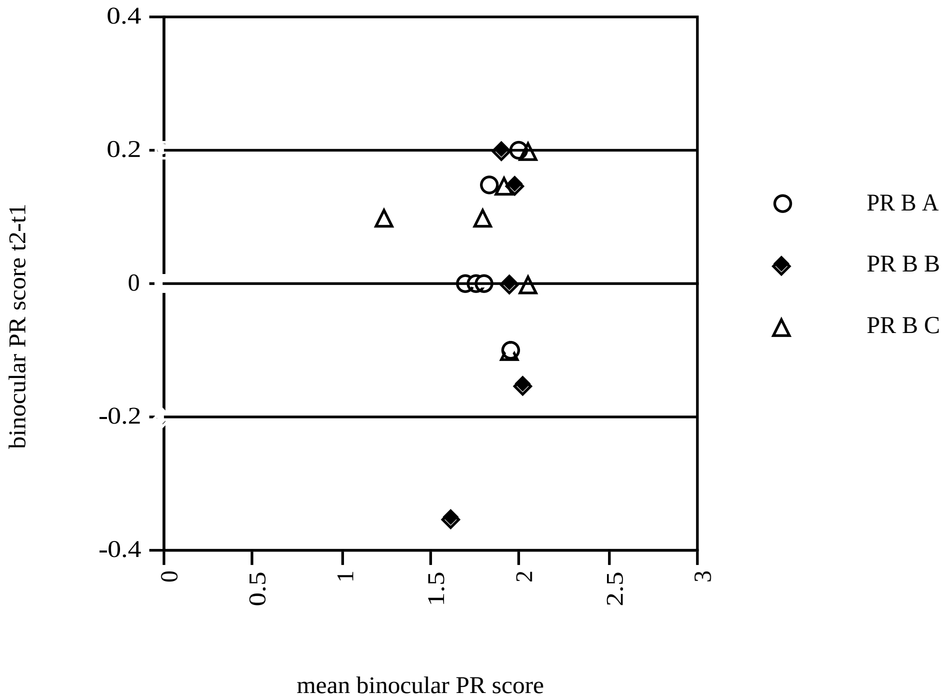

Figure 6.5.12 Difference of binocular scores for PR chart at t1 and t2 plotted against the mean of the same for all groups.

6.5.3 Discussion

On each graph there are points which lie outside the limits for a significant change both for increases and decreases in vision. Possible explanations for this are that one of the measurements for the point in question did not reach threshold creating a greater difference in results than would have been obtained if both measurements were at threshold. Other anomalies such as tearing and squinting which may always be present despite experimental vigilance could also account for these differences.

In both the monocular and binocular cases there appears to be a trend for improvement in score for lower vision (see figures 6.5.4 and 6.5.10). This trend suggests a learning effect for the single optotype chart.

The graphs of change in charts score between the two testing times show no clear trends in the data. Also there were no significant changes in any of the groups for any of the chart measures taken. These results suggest that either vision therapy produces no effect on vision as measured by the charts used or the changes were too small and variable to show on the size of data sample presented.

Chapter 7
Physical Data

7.1 Baseline Data

7.1.1 *Initial Data*

The baseline physical data collected from all participants is shown in table 7.1.1.

	mean ± sd	*range*
non-cycloplegic autorefraction R (D)	-3.38 ± 2.06	-0.9 to -6.725
non-cycloplegic autorefraction L (D)	-3.49 ± 2.22	-1.075 to -6.8
cycloplegic autorefraction R (D)	-3.63 ± 2.33	-0.3 to -7.65
cycloplegic autorefraction L (D)	-3.89 ± 2.45	-0.525 to -7.45
radius of corneal curvature R (mm)	7.82 ± 0.24	7.41 to 8.28
radius of corneal curvature L (mm)	7.79 ± 0.24	7.42 to 8.22
axial length R (mm)	24.80 ± 0.88	23.48 to 26.09
axial length L (mm)	24.69 ± 0.97	22.91 to 26.48

Table 7.1.1 Baseline optometric data.

7.1.2.Cycloplegic versus Non-cycloplegic Autorefractions

The difference between the cycloplegic autorefraction and the non-cycloplegic autorefraction is plotted in figure 7.1.2. The difference between the two values is not significant (ANOVA p=0.62) although 3 values fall outside of ±2sd of the mean. Since there was no difference between the two results only the non-cycloplegic autorefraction was repeated for post-therapy data collection.

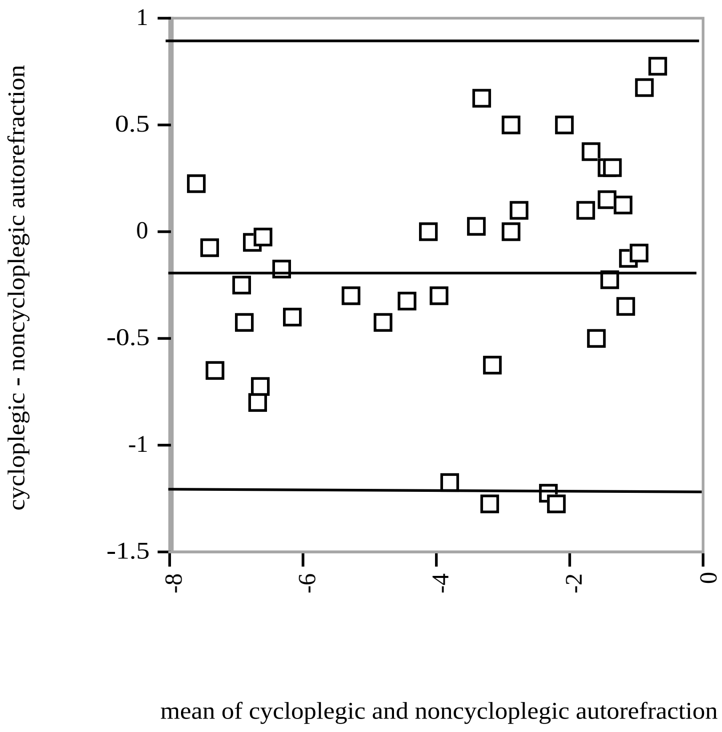

Figure 7.1.2 The difference between the cycloplegic and the non-cycloplegic autorefractor readings (mean sphere) plotted against the mean of the same for each subject. The solid lines represent the mean difference for all subjects and ±2stdev of the differences.

7.1.3 Corneal Curvature and Axial Length

The Gullstrand-Emsley schematic eye values (calculated from average population values) are 7.8mm for corneal curvature, 23.89mm for axial length and a refractive state of 0 (Bennett and Rabbetts, 1989). The mean corneal curvature found here (7.8mm) is therefore the same as those found previously for a normal population. The mean refractive error is different being more minus than the emmetropic value of zero. This result shows the myopic nature of the population chosen. The mean axial lengths found (RE = 24.80mm and LE = 24.69mm) are longer than that proposed for the schematic eye and this suggests that the myopia is due to the longer axial lengths.

7.1.4 Axial Length versus Prescription

The axial length versus the autorefractor readings are given in figure 7.1.4. This graph shows a relationship for which longer axial lengths are associated with larger negative refractive errors. The linear regression line shows that a change in axial length of 0.5mm will give a 1D change in the state of refraction. This gives a slightly lower prediction of the refractive change induced by a change in axial length than the calculated value of 1.4D for a 0.5mm change (Bennett & Rabbetts, 1989). Extrapolating the results predicts an axial length of 22.6mm for a refractive state of 0 (compared with 23.89mm for the schematic eye.) These results agree with those found previously in that there is a linear correlation between axial length and the refractive status (Carroll, 1982), the gradient of the slope of this correlation, however, was found to be -2.7mm/D as compared with -1.87mm/D here. This difference could be because of the restricted range of refractive errors presented here, (Carroll's data ranged from -15D to +10D).

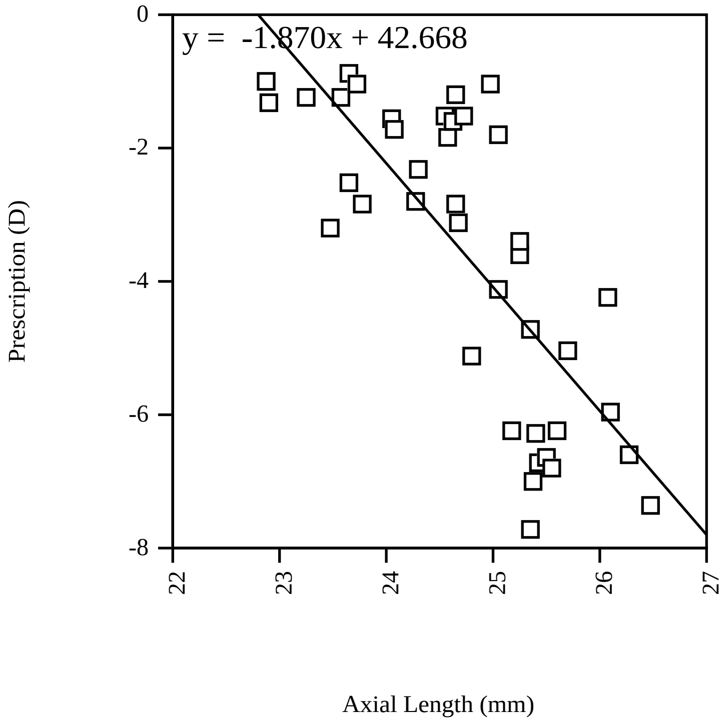

Figure 7.1.4 Prescription (mean sphere of noncycloplegic autorefraction for right and left eyes) plotted against axial length. R=0.767, p=0.0001.

7.1.5 Prescription versus Corneal Curvature

The mean sphere refractive error is plotted against corneal curvature in figure 7.1.5 and shows no obvious relationship. This suggests that the prescription is not determined by corneal curvature. When comparing myopes with emmetropes Grosvenor and Scott (1991) found significantly greater corneal power in the myopes. This suggests that although the results here show no relationship this is perhaps because the differences are small and the spread of refractive errors of the subjects was not great enough to show any differences.

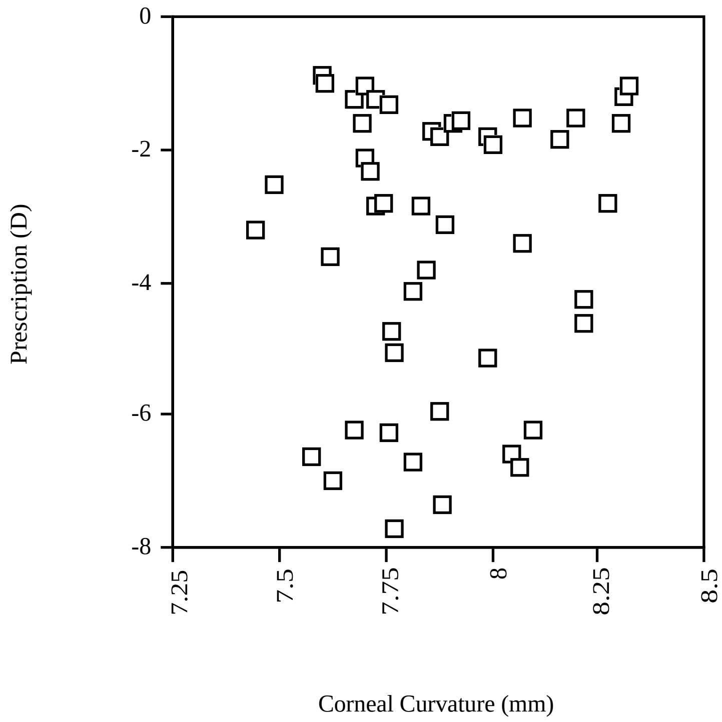

Figure 7.1.5 Prescription (mean sphere of noncycloplegic autorefraction for right and left eyes) plotted against the autokeratometry reading of corneal curvature. No relationship is observed.

7.1.6 Axial Length versus Corneal Radius Ratio

It has been reported that axial length/corneal radius ratio is highly correlated with refractive error with a value of 2.79 for emmetropia, 3.09 for early adult onset myopia and 3.21 for youth onset myopia (with the standard deviations not stated) being found (Grosvenor & Scott, 1991). The ratio for the data under discussion was calculated and the mean found to be 3.18 ± 0.11. This concurs with Grosvenor and Scott's findings and suggests that the subject group is a mixture of early adult and youth onset myopes weighted with more youth onset myopes.

7.1.7 Discussion

The physical data shows that there was no significant difference between the cycloplegic and non-cycloplegic refractions (see section 7.1.2). The mean corneal curvatures measured is the same as that which has been previously measured for a normal emmetropic population (see section 7.1.3). The mean axial length found was larger than that found for a normal emmetropic population suggesting that the myopia corresponds to the larger axial length (see section 7.1.3). A linear relationship between prescription and axial length was found for which a change in axial length of 0.5mm would give a 1D change in the state of refraction. No relationship between refractive error and corneal curvature was observed and the axial length/corneal radius ratio that was found agreed with previously found values (see section 7.1.6).

7.2 Pre and Post Therapy Optometric Data

Between 9 and 12 months after the initial data collection repeat measures were taken of the non-cycloplegic autorefraction and the autokeratometry reading. Repeat cycloplegic autorefraction measures were not taken since there was no significant difference between the initial cycloplegic and non-cycloplegic measures (see section 7.1.2). Any changes that would show up under cycloplegic autorefraction would, therefore, not be revealed. The initial data (t1) and the repeat data (t2) are compared for all three groups. The difference between the readings (t2-t1) is also shown. Where a subject withdrew the equivalent data entry in the initial group has been dropped for the purposes of comparison. The mean results and standard deviations from the autorefractor and the keratometer for each group are given in table 7.2.

	mean±stdev t2-t1 Group A(n=5)*	*mean±stdev t2-t1* Group B(n=5)*	*mean±stdev t2-t1* Group C(n=6)*
autorefractor R	0.06±0.18	-0.09±0.23	0.16±0.21
autorefractor L	-0.02±0.21	-0.18±0.15	0.03±0.30
keratometry R	0±0.01	0.03±0.04	0.01±0.02
keratometry L	-0.01±0.03	-0.01±0.01	0.02±0.02

Table 7.2 Mean difference of values of optometric measures at t1 and t2 for all groups.

From the table it can be seen that the results for the corneal curvature were very stable with almost no change in the readings at t1 and t2 for any of the groups. The results of the autorefractor readings are not stable although none of the group means changed by more than 0.18D. These results show no significant changes in the group means of these parameters and are plotted in figures 7.2.1 and 7.2.2.

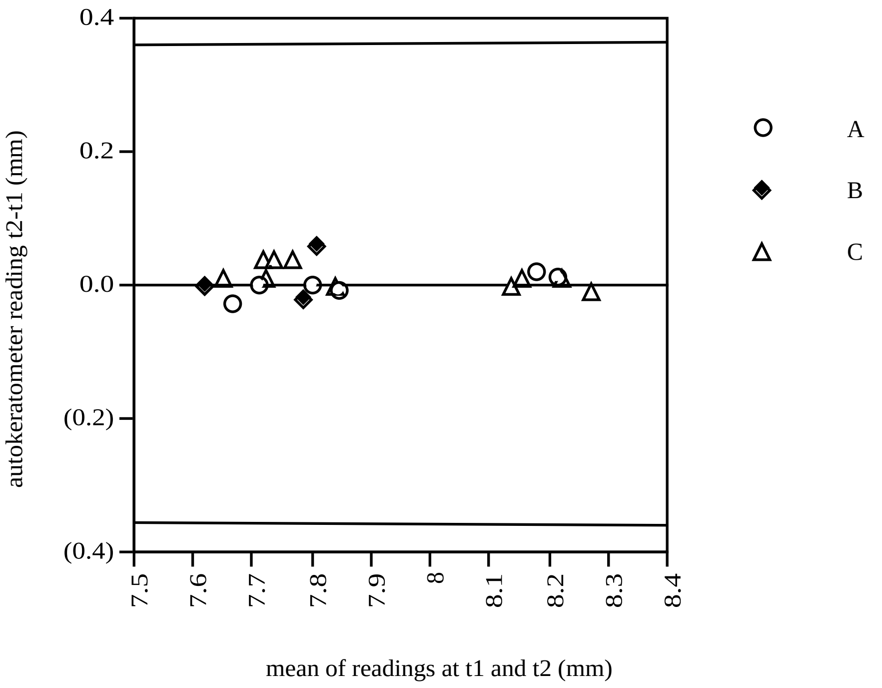

Figure 7.2.1 The final keratometry reading minus the initial reading for subjects in each group against their mean. The solid line shows zero change and the dashed lines show the confidence limit for change.

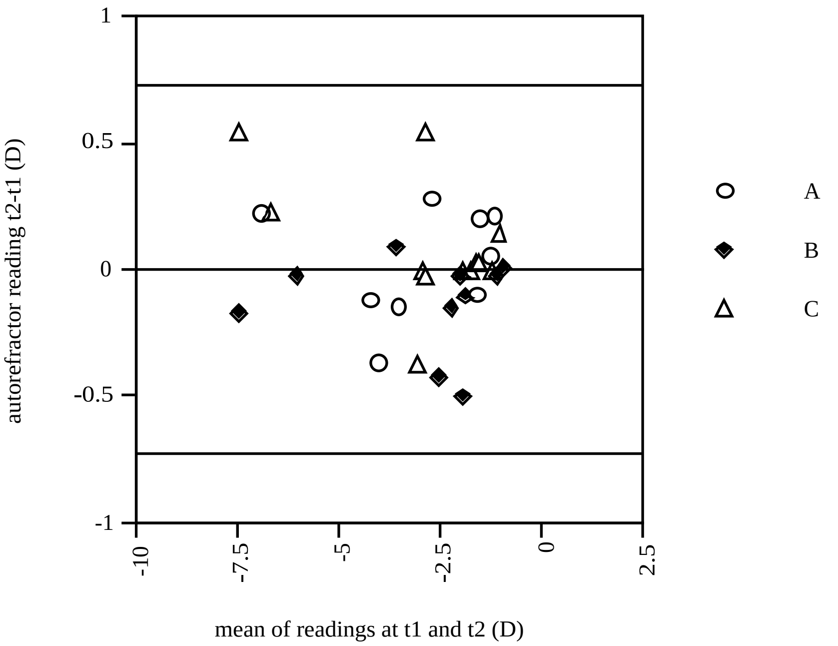

Figure 7.2.2 The final (non-cycloplegic) autorefractor reading minus the initial reading for subjects in each group against their mean. The solid line shows zero change and the dashed lines show the confidence limit for change of ±0.73D.

7.2.2 Axial Length

10 repeat axial length measures were taken, 8 from group C and 2 from group A. The mean of the results from group C were for the right eyes (n=4) 24.81±0.43mm at t1 and 24.68±0.51mm at t2. The left eyes (n=4) gave 24.59±0.50 at t1 and 24.95±0.53 at t2. For the subject in group A who had the axial length measurement repeated the results were as follows; right eye, t1, 23.58±0.07 and t2, 23.22±0.16, left eye, t1, 23.26±0.24, t2, 22.92±0.10.

7.2.3 Discussion

The results show no significant change in the parameters of corneal curvature or refractive status. Any change in prescription that would bring about changes in acuity as claimed by vision therapy would be small long term changes with possible large short-term fluctuations. The data collected for this study is all within the autorefractor's limits for a certainty of change and therefore it is concluded that no changes were observed in the state of refraction.

The axial length for the one subject in therapy group A that was collected reduced by 0.36±0.23mm in the right eye and 0.34±0.34 in the left. These changes would correspond to about 0.7D or about 4 letters (one short of one line) on the Bailey-Lovie chart. This compares with a decrease of 0.13mm and an increase of 0.36mm in the means for the group C axial length data.The confidence limit for change for the axial length measurements is ±0.35mm (see table 5.1.4) and so the changes observed are well under or borderline with this amount. The data numbers are too small, however, to make any conclusions as to the changes in axial length.

Chapter 8
Experiential Data

8.1 Experiential Data

8.1.1 Interview Texts

There are claims made about vision therapy (in particular the effects of the practises of shifting, palming and peripheral vision stimulation) which have not been monitored in this study. In order to try and gain some information about these techniques and their effects the participants who had sessions with the vision therapist (group A) were interviewed about their experiences. These interviews were used to see if there were any signs of things that are not measured by the optometric techniques used (e.g. fluctuating vision, expanded peripheral awareness, greater visual comfort) and to examine possible routes for further study.

Among the observations that were made in the interview texts the participants commented on noticing differences in their vision during the vision therapy sessions. This, however, was not experienced by everybody who took part. There follows some quotations from the interview texts to illustrate instances in which improvements were experienced after palming, peripheral vision stimulation and eye movement work.

No. 1: I started palming again and I do generally notice that it does help.......The main thing I find is my vision. I find it just sharper again.

No.7: I was doing the stuff with the peripheral vision which I'd never noticed before either.
A. What did you notice with your peripheral vision?
No. 7: I noticed that...I became more aware of it, that things were starting to become clearer, which I'd never, never seen before...But, yeah, it was really weird how the chart did become so much clearer...it wasn't like all of a sudden the letters all became clear, it was very much they came into focus and out of focus a lot more, whereas before it was all just out of focus.

No. 11: I could actually see things in the room which I couldn't see before...when the chart was stuck up at first I was like "oh no, I can't get it" but then later on it's like, well, I mean it was still blurred but I can make it out as opposed to not being able to make it out.

A: What activities make a difference?
No. 11: Following coloured balls, (see section 3.2.1) *that was the kind of thing that made me do it.*

Insert Table 8.1.1 here

See appendix 3 for the full interview texts. In addition to this one participant in group B who was particularly aware of her stereoscopic vision because of her work researching this area commented on noticing that without her glasses her vision was more three dimensional in nature and that with her glasses things appeared more flat. These instances of the experience of changing vision are presented as observations not immediately accessible to the research methods used in this work. No conclusions as to the efficacy or mechanisms of the techniques are drawn from these observations but they are presented because the experiences concur with the observations and claims made in chapter 3 and may be useful in determining future research (see chapter 9).

Table 8.1.1 was constructed by picking out themes from the interview texts (appendix II). 5 out of the 6 participants said that they experienced some sort of vision improvement, 4 people palmed regularly, 3 wore their reduced prescription regularly, 2 partially and one wore no prescription most of the time. 4 of the 6 said that they experienced improvements from some sort of vision exercises and 4 of the 6 also said that they would recommend vision therapy to other people.

Looking across the table there is a similarity in quality and tone of the responses to the different questions. For example no. 22 replies in the negative to most of the points whereas no. 1 is positive about each theme. Generalising this tendency means that those who experienced an improvement through palming and did home palming practise were generally positive about the experience. It is also of note that no. 22 who was the only participant to definitely experience no visual changes said that people close to him were dismissive of vision therapy techniques.

8.1.2 Vision Therapist's Reports

After the final therapy sessions the vision therapist was asked to give a brief synopsis of each participant.These are shown below with the initial and final chart scores for each participant on the Crowded Logmar Acuity Test, and the high and low contrast Bailey-Lovie charts.

Participant No. 1

No. 1 is minimally shortsighted. She is tight, controlled and intense. Glasses probably first prescribed because of exam stress. Work addressed her need to relax and let things be. She probably studies too hard with effort. "Soft focus" was encouraged. (Soft focus is the term used when equal attention is paid to every area of the visual field as compared with concentrated localised attention on a detail).

She was more or less without her glasses from the first time. She was frustrated by it but determined. She became used to it and it felt okay to go without her glasses. She palmed every day for extended periods. She has good days and bad days and is now noticing the fluctuations in her vision. She can not tolerate the reduced perscription although she was reading better with this at the last session.

With solid work could be out of her glasses with good vision. I would work more with right and left integration and do right handed work for balancing.

Chart	*Score t1*	*score t2*	*t2-t1*
CLR	0.845	1.05	0.205
CLL	0.97	1.075	0.105
CLB	0.775	1	0.225
BLR	0.76	0.8	0.04
BLL	0.8	0.92	0.12
BLB	0.96	1.0	0.04
LCR	0.46	0.62	0.16
LCL	0.64	0.74	0.1
LCB	0.84	0.88	0.04

Table 8.3.2a Vision scores on CLAT, BL and LCBL for each eye and binocular viewing for subject number 1.

Participant No. 2

The sessions were difficult and flat. He was probably bored at school and frustrated with his work. He was uptight and tense and described himself as easy going but I would dispute that. He reported that he had high blood pressure. He stayed tight and I don't think that he did any work at home.

Initially he said his glasses were too strong and he wasn't happy with them. He settled well into the reduced prescription but he probably appreciated the support more than anything else. He is trapped in a difficult position and not motivated to change his vision.

He got enormous benefit from palming and could get fluctuations from 6/30(0.3) to 6/15(0.6) during the sessions.

His vision could be better but it is unlikely that circumstances will allow for it.

Chart	*Score t1*	*score t2*	*t2-t1*
CLR	0.45	0.7	0.25
CLL	0.45	0.6	0.15
CLB	0.625	0.8	0.175
BLR	0.54	0.44	-0.1
BLL	0.5	0.46	-0.04
BLB	0.7	0.58	-0.12
LCR	0.24	0.2	-0.04
LCL	0.22	0.2	-0.02
LCB	0.34	0.22	-0.12

Table 8.3.2b Vision scores on CLAT, BL and LCBL for each eye and binocular viewing for subject number 2.

Participant No. 7

No. 7 didn't wear her glasses all the time anyway and didn't ever wear them for studying. She puts a huge effort into everything she does. There is quite a difference between right and left for her. Her binocular vision tests slightly worse than the left eye alone yet was preferable to her showing that the eyes worked together comfortably.

She palmed from the beginning and went around without her glasses. She didn't mind the blur. She probably had a lot better vision than was tested. She did well with her reduced prescription but we had to change it again to get stereoscopic vision back. The gap between the eyes narrowed giving greater balance.

She experienced big changes in vision during the sessions 6/21(0.5) to 6/9(0.8).

She has the potential for averagely good vision without glasses. Quite a lot more work is needed especially with right/left balance. She is still palming and it is now part of her routine.

Chart	*Score t1*	*score t2*	*t2-t1*
CLR	0.295	0.325	0.03
CLL	0.6	0.775	0.175
CLB	0.625	0.8	0.175
BLR	0.1	0.3	0.2
BLL	0.62	0.7	0.08
BLB	0.7	0.7	0
LCR	-0.15	-0.06	0.09
LCL	0.34	0.4	0.06
LCB	0.52	0.42	-0.1

Table 8.3.2c Vision scores on CLAT, BL and LCBL for each eye and binocular viewing for subject number 7.

Participant No.11

No. 11 got improvement from palming from the start. He talked about having low self-esteem and not being confident. He was strained about everything. He could go from 6/60(0) to 6/15(0.6) during a session. He adjusted well to the reduced prescription and would wait for the blur to clear. He wears it all the time.

We did lots of postural work and work with peripheral vision went well. I think he enjoyed the process and he made steady progress. He would arrive stressed from work and then palm and see better. Tension is a problem for him. Both eyes were similar and worked well together. His vision with the reduced prescription went from 6/12(0.7) to 6/6(1.0).

With more work he will get better vision. He did the work and was reliable.

Chart	*Score t1*	*score t2*	*t2-t1*
CLR	0.55	0.525	-0.025
CLL	0.575	0.6	-0.025
CLB	0.675	0.675	0
BLR	0.7	0.62	-0.08
BLL	0.46	0.46	0

BLB	0.62	0.58	-0.04
LCR	0.14	0	-0.14
LCL	0.04	-0.06	-1
LCB	0.04	0.12	0.08

Table 8.3.2d Vision scores on CLAT, BL and LCBL for each eye and binocular viewing for subject number 11.

Participant No. 22

No. 22 had very unbalanced vision with a big difference between the eyes. He was uptight and precise and not aware of eyestrain. Now he may be more aware of it.

He never did any work outside the sessions and didn't palm. He had a low frustration tolerance and wouldn't be without his glasses.

If he was interested in doing more work I would work with the left eye, but I don't think that he is motivated.

Chart	*Score t1*	*score t2*	*t2-t1*
CLR	0.475	0.675	0.2
CLL	0.45	0.225	-0.225
CLB	0.675	0.775	0.1
BLR	0.38	0.52	0.14
BLL	0.25	0.16	-0.09
BLB	0.6	0.64	0.04
LCR	0.12	0.34	0.22
LCL	0.495	-0.1	-0.595
LCB	0.32	0.4	0.08

Table 8.3.2e Vision scores on CLAT, BL and LCBL for each eye and binocular viewing for subject number 22.

Participant No. 24
No. 24 is highly myopic and he likes his glasses. He likes seeing easily, has no reason to change and is happy to stay in his prescription. Very low motivation. He probably would have lasted no more than 2 sessions privately.

Chart	*Score t1*	*score t2*	*t2-t1*
CLR	0.35	0.3	-0.05
CLL	0.075	0.01	0.025
CLB	0.18	0.175	-0.005
BLR	-0.13	0.06	0.19
BLL	-0.13	-0.1	0.03
BLB	0.05	0.06	0.01
LCR	-0.33	-0.3	0.03
LCL	-0.23	-0.18	0.05
LCB	-0.15	-0.04	0.11

Table 8.3.2f Vision scores on CLAT, BL and LCBL for each eye and binocular viewing for subject number 24.

The comments illustrate the holistic approach to vision work and also highlight the fact that although they are grouped together for the purposes of numerical analysis the participants who attended the vision therapy sessions each had a different experience of the work.The chart scores show how the individuals scored in an optometric testing situation before (t1) and after (t2) vision therapy.

8.1.3 Questionnaires
16 pre-therapy (t1) questionnaires were returned (6 from group A, 4 from group B and 6 from group C). After 1-6 months (t2) the same questionnaire was sent to the participants and 13 returned (5 from group A, 3 from group B and 5 from group C). 20 questionnaires were used for analysis, those from groups A and C at t2 and the corresponding questionnaires at t1.

Group A were significantly less comfortable with their vision after they started working with their vision (question 1, t-test p= 0.0004). There were no significant differences to the answers to the other questions. The following shows the question number followed by the p-value for the other questions (see section 5.7.5 for the questions). 1(.0004) 2(.914) 3(.0569) 4(.0477) 5(.91) 6(.159) 7(.47) 8(.9).

8.2 Discussion

Those participating reported changes in their vision - short term fluctuations which could be quite large. This suggests a flexibility in the visual system which could be due to

1) more efficient processing of blurred images
2) change in the state of refraction produced by a relaxation of accommodation by the ciliary muscle or changes in axial length

Whatever the local mechanisms these changes have only been observed when vision work is approached holistically.

Questionnaire data show that those taking part in the vision therapy sessions found their vision less comfortable. If a situation of reduced vision is indicative of strain it may well be the case that the person will be unaware of that strain. Any attempt to change this situation of strain will only be possible if he or she first of all becomes aware of it. This in itself can be an uncomfortable process and could account for this finding.

The vision therapist's reports illustrate the holistic nature of the work. The comments involve a discussion of how much work each person put in but also their own personal circumstances which may have prevented them dedicating a lot of time to the work. It also shows the emphasis placed on balancing the right and left sides of the body.

The approach that was taken with each participant was different and addressed their own particular needs, strengths and weaknesses.

There is a lack of consistency between the vision therapist's reports and the chart testing scores i.e. those that improved in the sessions did not neccessarily score well in controlled conditions. Also, however, of note is No. 22 who did score higher on the charts after the therapy period but did not report any improvement during the sessions.

The experience of vision therapy and the vision therapist's reports suggest a variability in vision that is faster (over seconds, minutes or hours) that can be recorded using conventional chart testing techniques, or which can not be produced on demand. It also suggests a great range in this variability (up to 3-6 lines of a test chart).

Chapter 9
Discussion and Conclusions

9.1 Vision and Visual Acuity Data

9.1.1 Differences Between the Charts

How a vision chart is designed alters the angular size of the smallest recognisable letter. This indicates that the results of a vision test in cases of ametropia is dependent on more than the degree of refractive blur.

The contrast of a chart is a major factor in chart scores obtainable and it was found that scores for the low contrast chart were lower than for the high contrast charts. This difference was found to be significantly greater for uncorrected vision than for corrected visual acuity. Exploring this difference further the slopes of the fall in chart score with refractive error can be considered (see figures 6.3.2 and 6.3.6). These graphs show that the rate of decline in chart score with refractive error is the same for both high and low contrast Bailey-Lovie charts. This result suggests that there is not a relative difference between the chart scores for different degrees of myopic blur when there is a difference between the corrected and uncorrected situation. Extrapolating these graphs predicts a difference between the two charts of 0.27 for a refractive state of 0. The mean observed difference for the corrected scores was 0.19 (see table 6.22). This result suggests a difference in the quality of corrected myopic vision, that is, the chart results do not extrapolate linearly from myopic blur to corrected clarity. Emmetropic data could be collected to find out if emmetropes conform to the uncorrected myopic trends, those of the corrected vision or neither.

The proximity of the other letters on a testing chart also affects performance. Single optotypes scored about one line more than the high contrast Bailey-Lovie chart for both the corrected and uncorrected situations. Assuming that this difference is due to the crowding effect of the surrounding letters on the BL chart suggests that crowding affects corrected and uncorrected myopia by the same amount.

The quality of fixational eye movements also play a role in vision. The Regan Repeat Letter chart has repeated letters in the centre and was designed to measure acuity independent of abnormal fixational eye movements (see section 5.2.2). It was observed (see section 6.2) that the relative difference between the scores of the RRL chart and that for the BL chart were significantly different in the case of corrected acuity as compared with uncorrected vision. This result indicates a need for an investigation into the role of fixational eye movements and myopia as it suggests a difference in the quality of these movements when refractive correction is worn. Again, emmetropic data would determine whether or not the difference was simply due to the level of acuity or whether it was only true in the presence of negative refractive correction.

9.1.2 Differences between Binocular and Monocular Viewing

The difference in score between monocular and binocular viewing in the corrected situation as compared with the uncorrected situation was analysed (see section 6.4.1). The standard deviations were much larger in the uncorrected situation suggesting that different refractive errors have a greater variability in the benefit gained by binocular viewing. Any difference between the uncorrected and corrected situation was found, however, not to be significant.

9.1.3 Pre and Post Therapy Data

There were no significant differences found between the data before therapy and the data after therapy. It is therefore concluded that vision therapy had no effect on the chart scores of the participants.

9.2 Physical Data

The physical data was collected in order to try to establish physical links to any changes in vision which may have been observed during vision therapy. It also allows relationships between the state of refraction and physical parameters to be made. There was no difference between the cycloplegic and non-cycloplegic autorefractions observed. A linear relationship between axial length and the state of refraction was found with longer axial lengths corresponding with larger negative refractive errors. No relationship between refractive error and corneal curvature was found. This result suggests that all the myopia of the participants was axial.

After the vision therapy no change was observed in the parameters of corneal curvature or refractive status. There was not enough data to establish whether or not a change in axial length was observed, however, since no significant change in vision or refractive status both of which are highly correlated with axial length, was recorded it seems unlikely that this parameter would have shown a change.

9.3 Experiential Data

Those participating reported changes in their vision - short term fluctuations which could be quite large. This suggests a flexibility in the visual system which could be caused by:

1) more efficient processing of blurred images
2) change in the state of refraction produced by a relaxation of accommodation by the ciliary muscle or changes in axial length

Whatever the local mechanisms these changes have only been observed when vision work is approached holistically.

Questionnaire data show that those taking part in the vision therapy sessions found their vision less comfortable. If a situation of reduced vision is indicative of strain it may well be the case that the person will be unaware of that strain. Any attempt to change this situation of strain will only be possible if he or she first of all becomes aware of it. This in itself can be an uncomfortable process and could account for this finding.

The vision therapist's reports illustrate the holistic nature of the work. The comments involve a discussion of how much work each person put in but also their own personal circumstances which may have prevented them dedicating a lot of time to the work. It also shows the emphasis placed on balancing, especially the right and left sides.

The approach that was taken with each participant was different and addressed their own particular needs, strengths and weaknesses.

There is a lack of consistency between the vision therapist's reports and the chart testing scores i.e. those that improved in the sessions did not neccessarily score well in controlled conditions. Also, however, of note is No. 22 who did score higher on the charts after the therapy period but did not report any improvement during the sessions.

The experience of vision therapy and the vision therapist's reports suggest a variability in vision that is faster (over seconds, minutes or hours) that can be recorded using conventional chart testing techniques. It is also suggest a great range in this variability (up to 3-6 lines of a test chart).

9.4 General Experimental Points

Changes in decision making criteria will also affect chart performance. Jogging and cycling can improve chart measures and it has been argued that this is due to the change in decision criteria brought about by the positive mood changes that occur after exercise (Woods & Thomson, 1995). Improved acuity was also observed in one trial after muscle relaxation and postural training (Konno, 1997).

The amount of encouragement given during measurement can also have an effect. Two different styles of taking chart measurement are 1) readily accepting the point where the patient or subject states that they cannot see any more or 2) taking unhurried measurements giving plenty of encouragement and 'forcing' guesses. Ideally to reach a point of threshold the latter method which is in effect a forced choice procedure should be used. This is especially true of the low contrast charts for which the letters often become visible only after prolonged inspection and scores tend to be 0.15 log units lower if a patient is not given sufficient time to look at the chart near threshold (Elliott & Whitaker, 1992). In this study the participants were given positive reinforcement irrespective of their accuracy and asked to continue reading until a point where mistakes were being made was reached, that is, "good" was said after every attempt.

Measurements taken in the blurred condition have a greater variability because: 1) there is a greater margin for guesswork and hence a flexibility in decision criteria and 2) if the holistic perspective is adopted there is a variability in vision which will be greater when uncorrected.While measuing the acuity of patients with uncorrected myopia one study observed that "subjects often reported scanning the edges or perimeter of the letters to help in recognition" (Bradley et al, 1991). This can be compared to the *shifting* exercise described in chapter 3 (see chapter 6 for a discussion of this point). People with poorer vision also tend to improve on retest by a few letters (see figure 9.4). When viewing the charts without glasses participants often reported seeing 2 or more images. This was most noticeable for the case of single letters. This phenomenon of monocular diplopia in the presence of defocus has been successfully modelled (Woods et al, 1996).

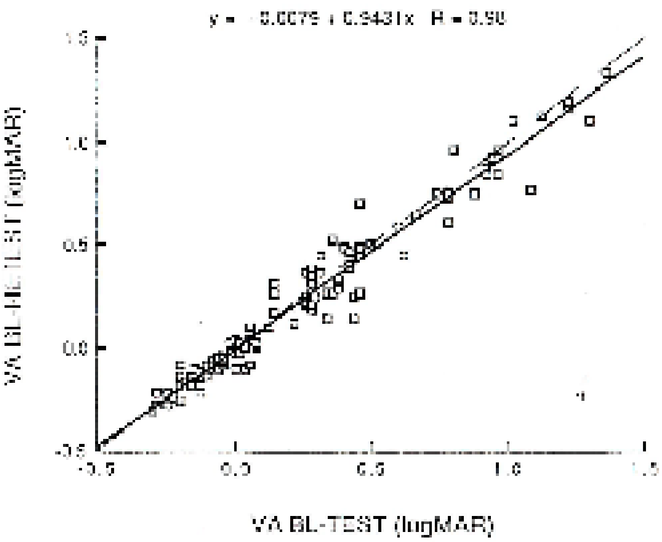

Figure 9.4 Test-retest relationship for vision measured with the Bailey-Lovie chart (solid line is regression line; dashed line is 1:1 line) (Lovie-Kitchin, 1988). The scoring used in this figure is the Bailey-Lovie LogMAR (0 is equivalent to 6/6) See table 5.3.

Even if a holistic method of analysis is not adopted in order to try to explain vision therapy understanding the process is not simple. Visual behaviour is a complex process dependent upon multiple factors. These may include: attention to task, motivation to perform, ability to discriminate stimuli, clarity of the image on the retina and neural processing of the retinal stimulation. There is no reason to expect that only one of these factors will be impacted by training (Collins & Gil, 1984). With this sort of framework a full discussion of myopia becomes unwieldy and impossible. If the factors of posture and environment etc. are also included the situation becomes even worse. There is at present a compartmentalisation of the various symptoms associated with myopia which needs the synthesis of a coherent theory.

9.5 Researching Holistic Vision Therapy

Holistic vision therapy claims to increase spatial, colour, movement and depth awareness. It also claims to improve the fluidity of eye movements, improve body posture and to decrease levels of anxiety and muscle tension. Although it is also claimed that vision can improve it is all the above elements which precede and are involved in the improvement. None of these elements were investigated in the experimental work. This was due, not only to a lack of expertise in researching these areas but also because of the nature of the experimental methodology.

Contemporary research in optometry, as with all research, is based on certain assumptions and principles which stand in place to make sense of the research. In optometry which is the study of the biological system of vision, the aim of the scientific study is to understand vision as far as possible. Alongside this is the practical application of this understanding in the form of medical intervention (e.g. spectacles prescribed for myopia). The assumption is that the best way to do this is to examine the intricacies of the system in as much detail as possible. "The argument for this detailed research (here the topic is nearwork, accommodation and myopia) is that only once the details of the mechanisms have been fully investigated and understood can any attempt at preventing and treating myopia be made" (Jiang & Morse, 1999). This as a philosophy of investigation runs counter to the premises of holistic healing.

Vision therapy is holistic and, as such, the more approaches that are being tackled at once, the more likely success is. There are many things that can be done and many outcomes expected e.g. a change in diet, exercise and motivation alongside vision exercises and a change of vision habits altogether are more likely to bring about changes in muscle tension, anxiety, posture, spatial awareness and visual quality as well as visual acuity.

In order to analyse this process breaking it up and compartmentalising it into component factors and dependent outcomes loses the essence and nature of the phenomenon. To try and find out which of the factors is more important and which outcome more likely although possible would be a difficult task. The only way to proceed using this technique is to eliminate as many variables as possible i.e. only change one thing at a time so that what causes any outcomes is clearly established. The problem with this approach to holistic vision therapy is that the more things that are being changed at once the more likely a change in vision is. Reducing the variables, therefore, reduces the chance of getting measureable results. As the field is examined more closely the number of variables keeps increasing. In order, therefore, for intelligible research in the field to proceed a theoretical approach which is not dependent on a reductionist model will be neccessary.

The holistic perspective also means that any direct link between a symptom, its cause and the treatment is impossible because there are no 1:1 relationships.

Chapter 10
Future Work

10.1 Postural Factors in Myopia

The main question to arise from this thesis is "Is myopia a holistic problem?" One possible approach to this would be to test the postural correlates speculated in chapter 3. This could be done by taking a postural expert e.g. an Alexander technique teacher and getting them to make an assessment of a group of myopes and a group of non-myopes. If any trends can be established, i.e. tension in the forehead, jaw, neck, shoulders, upper arms and lower back (Schneider et al, 1994), then the topic could be further investigated.

10.2 Peripheral Retinal Function and Peripheral Awareness

Within the natural vision literature it is reported that with myopia comes a reduction in peripheral awareness (Schneider et al, 1994; Goodrich, 1985) for which exercises stimulating the peripheral visual field is given. Also significant differences in the peripheral refraction of myopes, hyperopes and emmetropes have been found (Millodot, 1981) suggesting that peripheral refraction is related to the overall refraction in some way (McBrien & Barnes, 1984). It is hypothesised that emmetropia is a situation in which there is healthy functioning of all parts of the retina. In order to explore this topic experiments comparing visual fields and movement detection in people with different refractive states, both corrected and uncorrected could be done.

10.3 Imagery

The use of visual imagination has been shown to make a difference to experimental perception. In one experiment the observation that target detection can be facilitated with flanking visual masks was used to test the role of visual imagery in perception. It was found that imagining the flanking masks produced a similar enhancement of target detection (Ishai & Sagi, 1995). One of the natural vision techniques not discussed in this thesis is visual imagery. This can take the form of looking at an object, closing the eyes and sketching the object in the imagination and then opening the eyes and shifting around the object again observing as many details as possible. Another way that is suggested for doing this is the expansion of peripheral awareness and the use of visual imagery techniques emphasising distance vision to allow the experience of feelings associated with accommodative relaxation. (Birnbaum, 1981; Friedman, 1981). More experiments in the style of those by Ishai and Sagi could be done to explore this topic more fully.

10.4 Perceptual Metrics

In chapter 3 there is a passage in which someone who has undergone vision therapy describes her changing visual perception and describes it as "space expanding". In order to analyse this type of perceptual experience a framework can be devised to describe spatial concepts.

A metric is the set of rules defining distances between points in any space, for example, in 3-D Euclidean space the metric is described by the rule that the distance between two points (x_1, y_1, z_1) and (x_2, y_2, z_2) is given by $\sqrt{(x_2-x_1)^2+(y_2-y_1)^2+(z_2-z_1)^2}$. This expression would not apply in a different metric, for example on the surface of a sphere. This concept of a metric can be used to aid description of perceptual awareness and there have been attempts to describe vision, kinesthetic awareness and an awareness of the location of sounds in terms of metrics (Andrews, 1964). As a description of individual experience these metrics are necessarily subjective phemonena and can be flexible. It has been shown that with the application of lenses which severely distort the incoming visual information the visual system will adapt and recoordinate the visual information to agree with other sensory clues (e.g. balance). A less extreme example of this is the reported experience of difficulty walking down stairs for an initial period after receiving a new spectacle prescription.

This adaptation is not just a static effect and similar adaptation is possible in response to an environment moving at different speeds as well as those differing spatially. This is demonstrated in the waterfall illusion in which an observer watching a waterfall for a time and then altering the gaze to a static scene will observe the scene rushing upwards (Sekuler & Blake,1994). In this context the practises of shifting and swinging could be seen as exercises in motion adaptation teaching the perceptual system the metric needed for the physical motion of the body and the eyes.

A more detailed analysis using metrics could allow for quantification of three dimensional perceptual phenomena and with careful experimentation an analysis of the effect of refractive lenses and vision therapy on these personal perceptions may be possible.

10.5 Changing Awareness

When participating in vision therapy for myopia reduction there has been a reported increase in the perception of colour intensity. This phenomenon could be investigated.

The relationship of details to context is also reported to change. Myopia can be described as an increased attention to detail. Therapy work encourages peripheral awareness to expand a narrowed visual function to a global way of working. Metaphors for emotional work can be found in this with the relationship of context to details being out of balance. Myopia in this sense can be described as a lack of context.

10.6 Clinical Vision Therapy

In order to further explore what happens to people and their vision when natural vision techniques are used then the resource of natural vision teachers should be used in order to collect case study data and increase knowledge of the area. In order to achieve this documentation, however, there are real issues of communication which need to be addressed. The aims of optometric analysis and the aims of therapeutic work are quite different (therapy being about balance and integration of the person to a position of general health, optometric analysis the taking of specific measurements) and there exists at present suspicion and distrust between the fields. This means a general status quo in which the information on developing techniques and novel case studies are not being collected and used for furthering the understanding of how vision works in the more widespread scientific community. In order to reverse this situation and assimilate these new situations into current knowledge a sensitive approach to information gathering needs to be adopted. At best a long term collection of case studies will provide data on the efficacy of the techniques.

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