Vision screening in the Southern and Tairawhiti DHBs:
An audit of the B4 School Check

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Abstract

Amblyopia, or 'lazy eye', describes visual impairment occurring due to abnormal cortico-visual development as a child, and is the most common ophthalmological condition in children. The critical period for visual development in the human extends from birth to the around the ages of 7-9 years, and the development during this time occurs competitively between fellow eyes. Thus, any impairment in retinal image quality, neuronal function or misalignment of the eyes can lead to neuronal suppression of an eye, which may cause impaired visual acuity of that eye. Amblyopia can lead to issues later in life, such as limitation of occupational choices, poorer functional vision if something happens to the better-seeing eye, and an increased risk of vision loss in the better eye compared to individuals without amblyopia.

Amblyopia treatment is effective, however, so long as it occurs before the critical period of child cortico-visual development, and so, many societies have some form of child vision screening, so that children with amblyopia can be treated while effective treatment is still an option. In 2008, a nationwide screening programme was introduced in New Zealand: the B4 School Check (B4SC), and, currently, there is little data regarding the efficacy of the vision screening portion of the B4SC.

This study primarily aimed to assess the accuracy of the B4SC vision screening, by determining the positive predictive value, negative predictive value, sensitivity, and specificity of the programme. This was done by collecting data regarding visual acuity and referral status for all children screened by the B4SC within the Southern and Tairawhiti DHBs, and cross-matching this to data collected regarding these children who also presented to community optometrists and DHB eye clinics in the Southern and Tairawhiti DHB regions for comparison.

This study found that the positive predictive value for the B4SC was 53.5%. The negative predictive value was found to be between 96.1 and 99.9%, sensitivity was between 35.3 and 95.1%, and specificity was between 93.5 and 97.0%. It found that visual acuity testing is accurate, while it does have a low positive predictive value, the screening is performing its function of identifying cases of reduced visual acuity, without missing many cases.
I would firstly like to acknowledge the fantastic opportunity, help, and advice with this project provided by my supervisors, Dr Logan Mitchell, and Dr Graham Wilson, who made this possible.

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# Contents

Abstract ................................................................................................................................. ii

Acknowledgements ................................................................................................................. iii

Contents ................................................................................................................................. iv

List of Tables ........................................................................................................................... viii

List of Figures .......................................................................................................................... x

List of Abbreviations .............................................................................................................. xi

Introduction ............................................................................................................................. 1

Chapter One - Physiology of Vision ...................................................................................... 2

  1.1 Introduction ..................................................................................................................... 2

  1.2 Refraction ........................................................................................................................ 3

  1.3 Retina .............................................................................................................................. 4

  1.4 The Brain ........................................................................................................................ 5

  1.5 Binocularity ..................................................................................................................... 6

  1.6 Normal visual development ......................................................................................... 7

  1.7 Critical Periods for Visual Development ..................................................................... 9

Chapter Two - Amblyopia ..................................................................................................... 11

  2.1 What is amblyopia? ....................................................................................................... 11

  2.2 Definition of Amblyopia .............................................................................................. 11

  2.3 The Cause of Amblyopia ............................................................................................ 12

  2.4 Amblyopia development ............................................................................................. 12

  2.5 Types of Amblyopia .................................................................................................... 13

    2.5.1 Refractive Amblyopia ......................................................................................... 14

    2.5.2 Strabismic Amblyopia ..................................................................................... 20

    2.5.3 Deprivation Amblyopia .................................................................................... 22

    2.5.4 Mixed Amblyopia ............................................................................................. 22

  2.6 Epidemiology of Amblyopia ....................................................................................... 23

  2.7 Cortical Changes in Amblyopia .................................................................................. 23

  2.8 Clinical Features of Amblyopia ................................................................................... 24

  2.9 Testing for Amblyopia ................................................................................................. 25

  2.10 Treatment of Amblyopia .......................................................................................... 30

    2.10.1 Timing of Treatment .......................................................................................... 30

    2.10.2 Treatment of Underlying Cause ....................................................................... 30
2.10.3   Penalisation therapy........................................................................................................... 31
2.10.4   Outcomes of Amblyopia Treatment .................................................................................... 31
2.10.5   Adverse Effects of Treatment ............................................................................................... 32
2.11   The Functional Impact of Amblyopia .................................................................................... 33

Chapter Three - Childhood Vision Screening .............................................................................. 35
3.1   What is Screening ....................................................................................................................... 35
3.2   Validity of Screening .................................................................................................................. 35
3.3   Requirements for a Screening Programme .................................................................................. 36
3.4   Why There Should be an Amblyopia Screening Programme in New Zealand ....................... 37
  3.4.1   Amblyopia as an important health problem ......................................................................... 37
  3.4.2   Accepted Treatment of Amblyopia ....................................................................................... 37
  3.4.3   Facilities for Diagnosing and Treating Amblyopia ............................................................... 38
  3.4.4   Latent Stage of Amblyopia .................................................................................................. 38
  3.4.5   Suitable Test for Amblyopia ................................................................................................ 38
  3.4.6   Acceptability of Amblyopia Screening to the Population ................................................... 39
  3.4.7   Natural History of Amblyopia .............................................................................................. 40
  3.4.8   Agreed Policy on Amblyopia Diagnosis and Treatment ..................................................... 40
  3.4.9   Cost-effectiveness of Amblyopia Screening ......................................................................... 41
  3.4.10  Amblyopia Screening as a Continuous Process ................................................................... 42
  3.4.11  Suitability of a Screening Programme for Amblyopia ......................................................... 42
  3.5   When to Screen for Amblyopia .............................................................................................. 43
  3.6   How to Screen for Amblyopia ............................................................................................... 44
  3.7   Examples of Societies with Some Form of Vision Screening ................................................ 45
  3.8   The B4 School Check .............................................................................................................. 47
  3.9   Efficacy of the B4SC ................................................................................................................. 48

Chapter Four - Aims ....................................................................................................................... 50
  4.1   Primary aim ............................................................................................................................. 50
  4.2   Secondary aims ....................................................................................................................... 50

Chapter Five - Methods ................................................................................................................ 51
  5.1   Inclusion Criteria ...................................................................................................................... 51
  5.2   B4SC database ....................................................................................................................... 51
  5.3   Southern and Tairawhiti DHB clinical records ........................................................................ 52
  5.4   Community optometrist clinical data ...................................................................................... 54
  5.5   Variables .................................................................................................................................. 55
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.6 Data analysis</td>
<td>56</td>
</tr>
<tr>
<td>5.7 Ethics and informed consent</td>
<td>57</td>
</tr>
<tr>
<td>Chapter Six - Results</td>
<td>58</td>
</tr>
<tr>
<td>6.1 The Study Population</td>
<td>58</td>
</tr>
<tr>
<td>6.2 Collection of Data</td>
<td>60</td>
</tr>
<tr>
<td>6.2.1 Optometry Data</td>
<td>60</td>
</tr>
<tr>
<td>6.2.2 DHB Data</td>
<td>62</td>
</tr>
<tr>
<td>6.3 B4 School Check Outcomes</td>
<td>63</td>
</tr>
<tr>
<td>6.4 Ethnicity</td>
<td>65</td>
</tr>
<tr>
<td>6.4.1 Ethnicity Comparison of all Children Included in the Study</td>
<td>67</td>
</tr>
<tr>
<td>6.4.2 Ethnicity Comparison of all Children Screened for Vision and who Failed</td>
<td>68</td>
</tr>
<tr>
<td>6.4.3 Ethnicity Comparison of all Children Included in Study Found to Have Reduced Vision</td>
<td>70</td>
</tr>
<tr>
<td>6.5 Socioeconomic Differences Between Southern and Tairawhiti DHBs</td>
<td>71</td>
</tr>
<tr>
<td>6.6 Visual Acuity Comparison</td>
<td>73</td>
</tr>
<tr>
<td>6.7 The 'Error' of Visual Acuity Screening</td>
<td>75</td>
</tr>
<tr>
<td>6.8 Ocular Abnormalities in the Study Population</td>
<td>76</td>
</tr>
<tr>
<td>6.9 Cycloplegic Refraction of Children in Study Population</td>
<td>80</td>
</tr>
<tr>
<td>6.10 Management of Children in Study Population</td>
<td>81</td>
</tr>
<tr>
<td>6.11 False Positive, False Negative, True Positive, and True Negative Outcomes</td>
<td>83</td>
</tr>
<tr>
<td>6.12 Positive Predictive Value</td>
<td>84</td>
</tr>
<tr>
<td>6.13 Estimation of Sensitivity, Specificity, and Negative Predictive Value</td>
<td>85</td>
</tr>
<tr>
<td>Chapter Seven - Discussion</td>
<td>88</td>
</tr>
<tr>
<td>7.1 Main Findings</td>
<td>88</td>
</tr>
<tr>
<td>7.1.1 How Well the B4SC Vision Screening Programme is working</td>
<td>88</td>
</tr>
<tr>
<td>7.1.6 Visual acuity screening accuracy</td>
<td>93</td>
</tr>
<tr>
<td>7.2 Other outcomes from this study</td>
<td>95</td>
</tr>
<tr>
<td>7.2.1 Amblyopia and Refractive Error Outcomes</td>
<td>95</td>
</tr>
<tr>
<td>7.2.2 Management of Amblyopia and Refractive Error</td>
<td>96</td>
</tr>
<tr>
<td>7.2.3 Southern DHB versus Tairawhiti DHB</td>
<td>97</td>
</tr>
<tr>
<td>7.2.4 Ethnicity and Vision Screening</td>
<td>99</td>
</tr>
<tr>
<td>7.2.5 Optometrist versus DHB Management</td>
<td>100</td>
</tr>
<tr>
<td>7.3 Methodological Considerations</td>
<td>101</td>
</tr>
<tr>
<td>7.4 Further Research needed</td>
<td>103</td>
</tr>
<tr>
<td>7.5 Key conclusions of this study</td>
<td>104</td>
</tr>
</tbody>
</table>
List of Tables

Table 1: PEDIG Categories of Amblyopia Severity ..........................................................25
Table 2: Types of VA Tests .............................................................................................28
Table 3: Societies with and Methods of Childhood Vision Screening .........................45
Table 4: Number of children in the SDHB eligible for B4SC Vision Screening and the main outcomes of this screening ........................................................................63
Table 5: Number of children in the TDHB eligible for B4SC Vision Screening and the main outcomes of this screening ........................................................................64
Table 6: Number of children in both the SDHB and TDHB eligible for B4SC Vision Screening and the outcomes of this screening .........................................................64
Table 7: Ethnicity Distributions in SDHB ......................................................................66
Table 8: Ethnicity Distributions in TDHB ......................................................................66
Table 9: Ethnicity Distributions in SDHB and TDHB ......................................................67
Table 10: Methods of VA Testing used by Optometrists and DHB Eye Clinics Used .................................................................................................................................74
Table 11: Mean ± standard deviation of VA results from B4SC and optometrist/DHB, and paired t-test ............................................................75
Table 12: Causes of Reduced VA and other Ocular Pathology in SDHB ......................77
Table 13: Causes of Reduced VA and other Ocular Pathology in TDHB .....................78
Table 14: Causes of Reduced VA and other Ocular Pathology in SDHB and TDHB ..79
Table 15: Mean and 95% Confidence Intervals for Cycloplegic Refraction in SDHB .................................................................................................................................80
Table 16: Mean and 95% Confidence Intervals for Cycloplegic Refraction in TDHB .................................................................................................................................80
Table 17: Management of Children Seen by an Optometrist in the SDHB .................81
Table 18: Management of Children Seen at a SDHB Eye Clinic ..................................81
Table 19: Management of Children Seen by an Optometrist in the TDHB .................82
Table 20: Management of All children seen by an optometrist or DHB eye clinic in SDHB or TDHB ..................................................................................................................82
Table 21: Screening outcomes and follow-up results for the SDHB .........................83
Table 22: Screening outcomes and follow-up results for the TDHB .........................83
Table 23: Screening outcomes and follow-up results for the SDHB and TDHB ........84
Table 24: Best-case scenario for B4SC Vision Screening outcomes in SDHB and TDHB........................................................................................................................................86
Table 25: Worst-case scenario for B4SC Vision Screening outcomes in SDHB and TDHB........................................................................................................................................87
List of Figures

Figure 1: Structures of the Eye ................................................................. 2
Figure 2: Diagram of Emmetropia ............................................................. 14
Figure 3: Diagram of Myopia .................................................................. 15
Figure 4: Diagram of Hypermetropia ...................................................... 17
Figure 5: Referral pathway for the B4SC .................................................. 48
Figure 6: Numbers of Children Seen at Optometrists, DHB eye clinics, and B4SC in SDHB .............................................................................. 59
Figure 7: Numbers of Children Seen at Optometrists, DHB eye clinics, and B4SC in TDHB .............................................................................. 59
Figure 8: Numbers of Children Seen at Optometrists, DHB eye clinics, and B4SC in both SDHB and TDHB ................................................................. 60
Figure 9: Number of Children in Study Seen at Different Optometry Practices in SDHB .............................................................................. 61
Figure 10: Numbers of Children Seen at Different Optometry Practices in TDHB ................................................................. 62
Figure 11: Ethnicity Distribution of Children in Study in SDHB ................. 67
Figure 12: Ethnicity Distribution of Children in Study in TDHB .................. 68
Figure 13: Ethnicity Distribution of all Children Who Underwent Vision Screening and Failed, in SDHB ................................................................. 69
Figure 14: Ethnicity Distribution of all Children Who Underwent Vision Screening and Failed, in TDHB ................................................................. 69
Figure 15: Ethnicity Distribution of Children with Reduced Vision (6/9 or worse) in SDHB .............................................................................. 70
Figure 16: Ethnicity Distribution of Children with Reduced Vision (6/9 or worse) in TDHB .............................................................................. 71
Figure 17: Percentages of SDHB and TDHB Populations in each SES Quintile ....... 72
Figure 18: Frequencies of Unilateral VA levels determined by B4 School Check Vision Screening .............................................................................. 73
Figure 19: Frequencies of Unilateral VA levels determined by Optometrists or DHB Eye Clinics .............................................................................. 74
Figure 20: Scatter graph comparing True VA versus Screening VA ‘error’ .............. 76
### List of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>B4SC</td>
<td>B4 School Check</td>
</tr>
<tr>
<td>BCVA</td>
<td>Best Corrected Visual Acuity</td>
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<td>CS</td>
<td>Contrast Sensitivity</td>
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<tr>
<td>CMDHB</td>
<td>Counties-Manukau DHB</td>
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<tr>
<td>DMHDS</td>
<td>Dunedin Multidisciplinary Health and Development Study</td>
</tr>
<tr>
<td>FN</td>
<td>False Negative</td>
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<tr>
<td>FP</td>
<td>False Positive</td>
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<tr>
<td>FSA</td>
<td>First Specialist Assessment</td>
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<tr>
<td>GPCR</td>
<td>G-protein Coupled Receptor</td>
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<tr>
<td>LGN</td>
<td>Lateral Geniculate Nucleus</td>
</tr>
<tr>
<td>logMAR</td>
<td>Logarithm of minimal angle of resolution</td>
</tr>
<tr>
<td>MAR</td>
<td>Minimal angle of resolution</td>
</tr>
<tr>
<td>NZ</td>
<td>New Zealand</td>
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<td>PEDIG</td>
<td>Pediatric Eye Disease Investigator Group</td>
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<td>PPV</td>
<td>Positive Predictive Value</td>
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<tr>
<td>QALY</td>
<td>Quality-Adjusted Life Year</td>
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<tr>
<td>RAMSES</td>
<td>Rotterdam Amblyopia Screening Effectiveness Study</td>
</tr>
<tr>
<td>RE</td>
<td>Refractive Error</td>
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<tr>
<td>SES</td>
<td>Socio-economic Status</td>
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<tr>
<td>TN</td>
<td>True Negative</td>
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<tr>
<td>TP</td>
<td>True Positive</td>
</tr>
<tr>
<td>UK</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>V1</td>
<td>Primary Visual Cortex</td>
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<td>VA</td>
<td>Visual Acuity</td>
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</tbody>
</table>
Introduction

The visual system of the human infant is immature: unable to steadily fixate on a given object, unable to resolve fine detail. But within the next 10 years of the infant’s life, that visual system will reach the level of functioning of a normal adult, to become a system able to discern fine details under a wide variety of viewing conditions, at different distances and in different directions, all with binocular fixation allowing for appreciation and processing of image disparity between the eyes (in all directions of gaze) into a sense of form and depth, or stereopsis. To appreciate this, one must understand the physiology of normal adult vision, appreciate the critical periods of visual development, and the susceptibility for interference with this process which can derail this normal development, and lead to life-long visual disability.(1)

Amblyopia is the most common ophthalmological condition in children, with a prevalence of approximately 1-4%(2), caused by abnormal cortico-visual development during childhood. Development of the visual system occurs competitively between fellow eyes, which means any impairment of the retinal image quality, neuronal function, or misalignment of the eyes can lead to neuronal suppression of an eye, possibly impairing visual acuity of that eye. Amblyopia can lead to issues later in life with limitation of occupational choices, poorer functional vision if something happens to the good eye, and an increased risk of vision loss in the better eye compared to individuals without amblyopia.(3)

Amblyopia treatment is effective, however, so long as it occurs before the critical period of child cortico-visual development: about seven to nine years of age.(4) For this reason, many societies have some form of child vision screening, so that children with amblyopia can be treated while effective treatment is still an option.

In New Zealand (NZ), there has been some form of vision screening for over the past 40 years, and in 2008 a nationwide screening programme was introduced, the B4 School Check (B4SC), which includes hearing and vision screening. As of yet,
there is little data regarding the efficacy of the vision screening portion of the B4SC.

Chapter One - Physiology of Vision

1.1 Introduction

Vision is the perception and appreciation of patterns of visible light, and is achieved by a coordinated effort of many specialised structures in the eye and brain. The eye functions like a camera, transforming objects in one’s field of vision into images onto a film at the back of the eye, and then converting these into neural signals for the brain to process. Thus, there needs to be structures in the eye specialised for refracting and condensing all the light in one’s field of view onto a screen at the back of the eye, and structures specialised for converting this refracted light into action potentials to go to the brain for processing and complex visual functions. The main structures of the eye are outlined below (fig. 1).

Figure 1: Structures of the Eye
1.2 Refraction

Refraction of light in the eye is achieved with two structures. Light entering the eye first strikes the cornea, a curved, transparent, tough layer of collagen, beginning the process of refraction to eventually form a focused image on the retina. The cornea is the more powerful refractive component of the eye, with a refractive power of around 43 dioptres. However, the refractive power and focal length for the cornea is normally constant.(5)

Light will next reach the other refractive element of the eye, the lens. The lens is a transparent, biconvex structure, essential in normal visual activity, and although it has less refractive power than the cornea, only between 13 and 26 dioptres, its refractive power is adjustable, unlike the cornea. It is this ability to adjust its focal length which enables one to look at objects near and far, and maintain a focused retinal image, through a process called accommodation.

Accommodation is achieved by the ciliary muscle, a sphincter muscle located circumferentially around the lens, and attaching radially to the lens via huge numbers of zonular fibres, suspending the it in its position. The ciliary muscle receives parasympathetic innervation from the oculomotor nerve, via the ciliary ganglion, from the Edinger-Westphal nucleus. When one looks from an object at a distance to one that is near, the ciliary muscle contracts, and the diameter of the sphincter opening decreases, which relieves tension on the zonular fibres, rounding the lens due to its innate elasticity.(6) A rounded lens has a greater refractive power, and thus the eye can focus an image onto the retina for objects that are closer.(7) Accommodation happens autonomically, when an object is not focussed onto the retina. If an object is not in focus (i.e. the focal point of the image is in front or behind the retina), there will be a blurred retinal image. When one focusses on a near object, their eyes will converge and pupils constrict, as well as having ciliary muscle contraction, a phenomenon known as the near triad.(8,9)
1.3 Retina

Once refracted by the cornea and lens, light is then focussed to form an image on the screen at the back of the eye, an outgrowth of the brain known as the retina. It is here that light is transformed into an action potential by photoreceptor cells deep in the retina, in a process called photo-transduction. The two types of photoreceptor cells are rods and cones. Cones are densely populated at the fovea of the retina, and are responsible for colour vision and high visual acuity.(10) There are three types of cones, which are specialised for detecting long, medium, and short wavelengths of light, corresponding to different colours of light.(11) Rods are optimised for vision in low levels of light, activated by a single photon, as opposed to hundreds of photons required to activate a cone.(12,13)

Photoreceptors cells contain the photopigment rhodopsin, a molecule that is vital to the process of photo-transduction. Rhodopsin is made of opsin, a type of G protein-coupled receptor (GPCR), and retinal, in an 11-cis isomer configuration. When a photon strikes rhodopsin, 11-cis retinal is converted to all-trans retinal, producing changes in the opsin to form metarhodopsin II, which then activates transducin, a G protein. Transducin leads to decreased levels of cGMP, closing Na+ channels, stopping a flow of Na+ into the cell, and thereby causing hyperpolarisation. This causes decreased release of glutamate, an excitatory neurotransmitter, that can bind to receptors on horizontal and bipolar cells and, depending on the type of receptor, will excite, or inhibit the cell. In the dark, cGMP levels are high, and cGMP-gated sodium channels remain open allowing a steady inward Na+ current, known as the ‘dark current’, keeping the photoreceptor cell depolarised, and increasing the levels of glutamate.(14,15)

Photo-transduction allows the conversion of light into a visual potential, and thus allows a means of signalling visual information to the brain. The photoreceptor cells will synapse with bipolar cells, which in turn synapse onto retinal amacrine cells. Both bipolar cells and retinal amacrine cells will synapse onto retinal ganglion cells, the axons of which comprise the optic nerve. The ganglion cell axons are firstly non-myelinated, as the axons pass over the rest of
the retina, but become myelinated once they reach the optic disc, the point where the optic nerve exits the retina.(16)

The receptive field of retinal ganglion cells refers to the space on the retina where changes to the stimulation of the photoreceptors there will affect the output from the ganglion cells. A smaller receptive field means that the ganglion cell has connections with fewer photoreceptor cells than in a larger receptive field, which means that a smaller receptive field can detect smaller differences between stimuli, increasing its discriminative ability. The receptive field organisation on the retina is maintained throughout the visual pathways in the brain.(17)

1.4 The Brain

The optic nerve carries all visual information from the retina. Fibres of the optic nerve carrying information from the nasal hemiretina of each eye (responsible for the temporal field of view) will decussate to the contralateral side, at a point known as the optic chiasm, and continue inside through the optic tract. Fibres from the temporal hemiretina do not cross, and will remain on the ipsilateral side of both the optic nerve and the optic tract. The two optic tracts relay visual information to the lateral geniculate nuclei (LGN) of the thalamus on each side ipsilaterally, as well as to the superior colliculi and pretectal areas of the brain. The optic radiation, made of axons from the neurons of the LGN, travels to and synapses on the primary visual cortex (V1).(18)

The cortical area responsible for vision is in the occipital lobe, which is divided into several functional areas, for differing levels of visual processing. The visual cortex consists of V1, as well as extrastriate areas (V2, V3, V4, V5).(19) V1 is organised into six layers, and is structured topographically to correspond to different areas of the retina so that, for example, the fovea is represented at the occipital pole, and the peripheral retina is represented in the anterior margin of the calcarine fissure.(20,21) V1 functions to interpret patterns of visual potentials into visual perception and cognition, and discern the size, orientation, and
direction of objects in a dynamic field of view, and, along with memory and other sensory context, describe what objects are and where they are moving.

V1 cell firing encodes for local features of images, particularly orientation, and many V1 cells respond to a preferred orientation of visual input, known as orientation selectivity. Also, many neurons will respond to one direction of motion of a visual stimulus more readily than others, known as direction selectivity. This property is thought to arise from a delay in inputs between cortical cells with the same orientation selectivity, and one cell enhancing or suppressing the response of the next one.(22) As there is a precise topographical map of the visual field represented in V1, Hubel and Wiesel proposed that V1 is organised as a series of repeating modules, which contains the necessary components to analyse one part of a visual field, termed hypercolumns.(23) Each hypercoloumn contains a left and right eye ocular dominance column, which are layers of cells that respond more to input from one eye or the other, for a given field of view. Ocular dominance columns contain high levels of a protein called cytochrome oxidase, and are thought to be important in binocular vision.(24)

1.5 Binocularity

Normal visual functioning requires the use of two eyes, and produces the perception of a singular visual reality. For binocular vision to be successful each eye must be able to move together in the same direction to maintain alignment, and the brain must combine two visually similar but slightly different images in a process called fusion, interpreting subtle differences between these images to determine differences in depth, or stereopsis.

Alignment and movement of each eye is achieved with six muscles around it, referred to as the extra-ocular muscles. Each eye has four rectus muscles, arising from a common tendinous ring, located postero-medially at the apex of the orbit. These are the lateral, superior, medial, and inferior recti, and generally move the eye in the direction suggested by their name. The other two extraocular muscles
are the superior and inferior oblique. These insert onto the eye behind its axis of rotation, so the superior oblique will depress the eye, (as well abduct it), and the inferior oblique will elevate the eye (as well as abduct it). The lateral rectus muscle is innervated by cranial nerve VI (abducens), which arises from the pons. The superior oblique muscle is innervated by cranial nerve IV (trochlea), arising from the midbrain. All the other extraocular muscles are innervated by cranial nerve III (the oculomotor nerve). The extraocular muscles work in conjunction, so that opposing pairs will act together, so each eye can move in conjugate gaze and maintain ocular alignment. (25)

Each eye will produce its own retinal image, but normally one only perceives a single image. The unification of the two retinal images into one is known as sensory fusion, a process is occurring in V1 and requiring two sufficiently similar retinal images; similar in size, brightness, and clarity. Motor fusion, also arising from V1, is the ability to be able to align the eyes so that sensory fusion is maintained. If there is disparity between the retinal images, this will stimulate eye movements to try to restore sensory fusion. (26, 27)

Stereopsis is the ability of the visual system to determine the depth between objects in one’s field of view. This function relies on the fact that the two eyes can fixate on the same object simultaneously, while also having a slight separation in space, meaning the eyes receive two slightly different images, as the eyes will have slight differences in the angle at which they are directed to the object. V1 can process these binocular disparities to determine how far away various objects are, and thus build a 3-Dimensional perception of the visual world. (28)

1.6 Normal visual development

The formation of the normal, mature visual system requires a number of anatomical and physiological changes in the eye and brain, which are occurring from infancy to about seven years of age. The visual system at birth, while allowing some crude vision, is still incomplete, and further development will be mostly
guided by visual experiences. (29) Changes to the visual anatomy include increase in globe length, changes to the retina, such as pruning ganglion cells, as well as the formation and specialisation of neuronal connections in cortical and sub-cortical visual centres, via growth and apoptosis. (30,31)

The development of the cortical visual centres is a complex process. Major outcomes from this growth include the development and refinement of complex visual functions, such as high visual acuity (VA), binocularity, stereopsis, contrast sensitivity, and motion sensitivity, and development of these will depend on both innate and stimuli-dependent factors. (32) The development of these processes happens by selecting for and cultivating the necessary neuronal networks that are stimulated by each eye. This happens via competitive inhibition between fellow eyes, each eye competing for consolidation of connections in V1 with its ocular dominance column. The two eyes each stimulate connections amongst cortical visual centres, which continually reinforces (or deteriorates, in the case of lack of stimulation) cortico-visual connections.

Postnatal vision development requires normal visual stimulation, specifically the presence high quality visual images which are concordant between fellow eyes. As the two retinae are stimulated with clear images that are sufficiently similar, so that they can be fused, the cortical areas responsible for vision (V1 and the LGN) mature. The density of neurons here increases, along with the strength of synapses. Normal visual development requires clear retinal images, equal image clarity and proper eye alignment, and so anything affecting one or more of these can lead to aberrant visual development. (33)

Striatal neurons are innately specialised for either binocular or monocular vision. As vision develops normally, equal proportions of monocular neurons become innervated by afferent neurons from the two eyes, and so each eye will develop equal synaptic representation in the brain.

Postnatally, VA is poor, due to the immaturity of V1 and the LGN. Infants also have increased use of para-foveal photoreceptors during fixation, meaning visual fixation is not utilising the densely packed cone photoreceptors of the fovea, the
area responsible for high visual acuity. Normally, VA rapidly improves as visual centres are stimulated with exposure to high quality retinal images, of equal and sufficient clarity, as well as proper eye alignment. Fixation begins to happen at the fovea, thus allowing a greater number of cones to be used. By ages 5-6 years, a child’s VA approaches the level of adult VA. Contrast sensitivity (CS), the smallest difference between to different contrasts of light that the visual system can distinguish, improves as cones develop at the fovea. The onset of binocular function and stereopsis in infants is about three months, and again, the development of these processes depend on clear and sufficiently equal retinal images.

1.7 Critical Periods for Visual Development

The critical period of visual development is a period during post-natal development when the visual pathways are highly plastic, and in which certain visual experiences are required for normal maturation. Visual experiences during a critical period can permanently alter the development of the visual system. Neuronal connections of the visual pathways are susceptible to experiential-dependent changes. The length of critical period of visual development in humans is usually thought to be around seven or eight years of age, though it is not precisely defined. The specific lengths of critical periods also differ between cortical locations, and in general, higher visual processing sites tend to have longer periods of plasticity.

Any changes which occurs in the LGN and V1 during the critical period are often unable to be reversed once the period is over, and so any aberrant changes that may have occurred during visual development will likely persist for the patient’s life. However, there is some evidence that the adult brain does retain some neuroplasticity. In people with amblyopia who lose vision in the ‘better’ eye, approximately 10% of them will have an improvement in their VA of the amblyopic eye, suggesting that there is some residual plasticity. However, the potential for
change and improvement to abnormal visual centres in an adult is greatly less than
the potential for change and improvement in a visually-developing child, and
therefore, children should still be the main recipients of amblyopia prevention and
treatment. (38)

More evidence for existence of critical periods is that full time vision deprivation
in an adult cat has no detectable effects, as opposed to monocular visual
depprivation in kittens, which has been shown to decrease vision in the deprived
eye. This has been used as a model for human amblyopia. (33)
Chapter Two - Amblyopia

2.1 What is amblyopia?

Amblyopia, or “lazy eye”, is the most common cause of visual impairment in children, and will often persist into adulthood. It is a cortical deficit which appears as a decrease in the best-corrected visual acuity (BCVA) in usually one eye, but potentially both, and there is a dysfunction in the processing of visual information. Amblyopia arises from abnormal visual stimulation during visual development.

2.2 Definition of Amblyopia

For this thesis, amblyopia will be defined using the same definition used for the B4 School Check: a reduction of the best-corrected visual acuity that cannot be attributed entirely to any other abnormality in the visual system.

There is a number of different definitions for amblyopia in the literature, however. Other commonly used definitions include a developmental disorder of spatial vision, or pathology resulting from optical deficits in childhood.

There is also variation in the literature regarding the exact quantitative definition of amblyopia, and what should be the visual acuity cut-off for clinical diagnosis, varying between regions, types of test used, and clinician preference. Commonly accepted clinical definitions of amblyopia include a BCVA of 6/12 or worse in either eye, a BCVA of 6/9 or worse in either eye, or a two-line logMAR difference between eyes, in the absence of other ocular or cortical disease to better explain the visual defect. Some definitions also require the presence of an amblyopia risk factor, such as strabismus or anisometropia.

Currently, there is debate on what levels of VA are normal in children, and what is a normal level of VA difference between eyes. It has been suggested that a VA of up to 6/12 may be normal in young children aged 3-4 years.
The B4SC Vision Screening Programme, the national vision screening programme for children at four years old in NZ, employs a BCVA of 6/9 or worse in either eye as the threshold for referral, i.e. a positive amblyopia screen, and hence will be the quantitative definition for amblyopia diagnosis used for this thesis.(42)

2.3 The Cause of Amblyopia

Amblyopia is caused by abnormal development of the cortico-visual system. Abnormal development of the visual system occurs secondarily to abnormal stimulation of the visual centres of a young child, and this may occur in any condition affecting the clarity and formation of a retinal image, or any condition causing significant differences between fellow retinal images.(48) While the cause of amblyopia is something that affects the formation of clear and balanced images on the retina, the actual locations of the changes that occur in amblyopia are in the brain, specifically in the lateral geniculate nucleus (LGN) of the thalamus, and the primary visual cortex (V1).(33)

2.4 Amblyopia development

Amblyopia can be caused by anything that leads to abnormal visual stimulation in early childhood, during the critical period of visual development. This abnormal visual experience can be either a reduced quality of visual input or abnormal binocular interaction, causing insufficient, or inappropriate, stimulation of visual centres, inhibiting normal visual development.(44)

Pattern deprivation can result from significant refractive error, blurring the image on the retina, or a media opacity, which obstructs the visual axis of the eye. Fine details are lost, which leads to cortical suppression of the visual pathways from that eye. Abnormal binocular interaction can result from strabismus, an ocular misalignment, or anisometropia, a difference in the refractive states of each
eye. This binocular discordance in a young child results in abnormal changes to the highly malleable visual cortex, as the brain is trying to process two images which are unable to be fused. Pattern deprivation and abnormal binocular interaction can occur independently or together. (49)

The eyes develop competitively with each other, and abnormal stimulation from one eye can mean there is decreased cortical activity in the areas representing that eye, and so, there may be fewer neurons selected to be driven by that eye in future visual activity. Monocular neurons from the abnormal eye begin to be crowded-out due to decreased stimulation, and some begin to differentiate into neurons driven by the fellow, better-functioning eye.

A blurred retinal image leads to that eye being selected against, while the 'better' eye is favoured, and will begin to dominate visual activity. Most visual-cortical neurons may come to represent the better-seeing eye. In amblyopia, the equal balance of neurons driven by each eye is lost. Eventually, in moderate to severe cases of amblyopia, most cells in V1 begin to only respond to stimulation from the better-seeing eye. (50) This may progress to the point where the amblyopic eye is absent from most vision, depending on the severity of the loss of image quality. (51)

Visual deprivation can lead to the cortical cells stimulated by the deprived eye becoming unresponsive to stimulation, and causes a sharp decrease in the number of cells that are driven by the afflicted eye. (33) This process is thought to occur due to a disruption of connections that are present at birth. (52)

2.5 Types of Amblyopia

Amblyopia can be grouped according to the underlying cause. The main causes of amblyopia are refractive error (RE), strabismus, and deprivation, and either one or a combination of these can lead to amblyopia.
2.5.1 Refractive Amblyopia

Untreated refractive errors in children may cause amblyopia, in addition to being a common cause of a reduced in visual acuity in children in themselves. Refractive errors in children include hypermetropia, myopia, astigmatism, and anisometropia. RE occurs when the power of the refractive system of the eye is not appropriate for its length. ‘Normal’ or ‘physiological’ refractive errors occur in young children aged around 1-4 years, when the power of the refractive system is not appropriate for the length of the eye, since the eye still must grow and increase its length. This creates a slightly hypermetropic refractive state, but this often normalises, in a process called emmetropisation, as the length of the globe increases, under stimulation from the hypermetropic refractive state.\(^{53,54}\)

Emmetropia is the state of normal refraction, when the refractive power of the lens and cornea is suitable for the length of the globe, so that a clear image is projected directly onto the retina, rather than in front or behind it (fig. 2). This maximises VA, as the retinal image is not blurry, and therefore the greatest amount of detail can be perceived.

Myopia

Myopia is a refractive error that occurs when light is focussed in front of the retina, instead of onto it. This can be due to the refractive power of the lens and
cornea being too great, or the length of the globe being too long (fig. 3). Myopia will mean that distant objects will appear out of focus, but does not usually affect the focus for objects that are closer. (55) When looking at objects that are further away, the lens is in its thinnest configuration, and thus in its position with the least refractive power. In the myopic eye, when looking at objects further away, its lowest level of refractive power is still too great, and thus the image is formed in front of the retina. However, when looking at an object that is closer, the lens will need to have an increased refractive power. This means a myopic eye looking at an object that is near already has sufficient refractive power, and can focus an image directly onto the retina.

Myopic children are usually not as likely to develop amblyopia compared to children with other types of refractive errors. Children with myopia usually have good near-vision, which is usually sufficient to provide the necessary visual activity for normal visual development. (56)

The clinical guidelines for the NZ Children’s Spectacle Subsidy for myopia in children aged four to six years is -1.50D or more, and so this will be the definition for myopia used in this thesis. (57)

The prevalence of myopia varies considerably, depending on race, age, country, and sex. Most myopia appears during childhood, particularly during school. In Asian populations, it has a relatively high prevalence of around 40-50%. In
Australia, the prevalence of myopia has been estimated at around 17% of the total population, and at about 8% of the population of children. (58–61)

The cause of myopia appears to be an amalgamation of genetic and environmental factors. Studies into the genetics of myopia have identified 18 potential loci that are associated with myopia. However, no single gene appears to be entirely causal, and the genetic basis appears to be an interaction of multiple genes. (62,63) Genetics does not entirely explain variation in myopia epidemiology, and there is also an environmental component to myopia, and environmental conditions seem to be a major cause in the increasing prevalence of myopia around the world. (69,70) Possible environmental factors affecting myopia development are the amount of outdoor activity and socialisation in childhood. (64)

Myopia can often be corrected by reducing the effect of the over-powered lens of the eye with concave corrective lenses, which have a negative focal length. The negative focal length can balance the relatively high power of the eye. This shifts the light rays entering the eye, so that they now focus onto the retina, rather than in front of it. Myopia correction is often quite successful. (65)

**Hypermetropia**

Hypermetropia is when the optical power of the eye is too weak, or the length of the globe is too short comparatively, and light is focussed beyond the retina (fig.4). The prevalence of hypermetropia is around 5-13% of the population, and it is more common in Caucasian populations. (58,66)
In adults, hypermetropia usually results in a reduction of near vision, while distance vision can remain somewhat normal. This is because when looking at objects that are distant, the increased refractive power required is able to be provided through accommodation. However, for objects that are close, the eye requires more refractive power, which may be more than can be comfortably provided by accommodation. Hypermetropia is often present from birth, but children have a rather flexible eye lens, which can often compensate for this hypermetropia. However, the refractive error will often present once there is loss of this accommodation, which happens naturally with age.

Infants with hypermetropia of +2.5 D or greater are 20 times as likely develop strabismus or amblyopia than their emmetropic peers. Hypermetropia greater than +4.50 is quite likely to cause amblyopia if untreated. (67) High levels of hypermetropia may cause bilateral amblyopia, as there can be decreased image quality on both retinae. This means that there is insufficient visual information being received, which may prevent the development of normal vision in the visual cortex.

The clinical guidelines for the NZ Children’s Spectacle Subsidy for hypermetropia in children aged four to six years is 2.50D or more, and so this will be the definition for hypermetropia used in this thesis. (57) Correction of hypermetropia is usually with spectacles, done using convex lenses, with a positive focal length, which can compensate for the relatively lower optical power of the eye.
Astigmatism

Astigmatism is when there is an irregular curvature of the cornea or lens. This means that rather than being spherical, the shape of the refractive system is asymmetrical, and the focal point of the eye differs in two different meridians (planes). The prevalence of astigmatism in children is estimated to be around 1-3%, and the prevalence is also thought to be higher in older children.(68,69)

Astigmatism may be asymptomatic in low severity cases, but high levels of astigmatism may lead to blurred vision, eye strain and headaches. Astigmatism greater than +4.50 is likely to cause amblyopia, particularly oblique astigmatism.(70)

The clinical guidelines for the NZ Children’s Spectacle Subsidy for astigmatism in children aged four to six years is 1.50D or more, and therefore will be the definition of astigmatism used in this thesis.(57) Treatment of astigmatism is with optical correction, such as spectacles. The corrective lenses are made in a way to account for differences in refraction in both planes. Treatment of astigmatism is very often successful.

Anisometropia

Anisometropia means that there is a difference in the refractive states between fellow eyes, either due to myopia, hypermetropia, or astigmatism, or a combination of these, which is not even between the eyes.

The significance of anisometropia is that the eyes are unable to focus on the same object simultaneously, and therefore will receive a different visual input. The two retinae will not have similarly refracted images, and thus there will be cortical binocular discordance. This causes a visual pathway from one of the eyes (usually the more ametropic) to be suppressed. Also, the significantly blurred retinal image of the more ametropic eye may lead to a further decrease in cortical development
for that eye. Over a sufficient period, this suppression and issue with development can cause amblyopia. Anisometropia is more amblyogenic than symmetrical RE, per unit dioptre, as it also allows for the favoured use and development of one side of the visual system. This is especially true for anisometric hypermetropia, as the child can accommodate to make either eye focus, but never both simultaneously, and will generally favour the least hypermetropic eye, as that requires the least accommodative effort.(71,72)

Anisometric amblyopia is usually milder than other forms of amblyopia, and often relatively treatable. Children with pure anisometric amblyopia have the best initial VA compared to the strabismic and pattern deprivation types.(73) This is perhaps since both eyes are participating in visual activity somewhat, even though the clarity of the image in one eye is diminished. However, a worse severity of anisometropia is correlated to a worse VA in anisometropic amblyopia.(74)

The prevalence of anisometropia can be difficult to measure, especially since there is differing definitions of the boundary of anisometropia and isometropia (equal refractive states between eyes). However, it has been estimated that anisometropia occurs in around 4-6% of children older than four years.(75–77) Anisometric amblyopia accounts for about a third of the cases of amblyopia.(44,78)

The clinical guidelines for the NZ Children’s Spectacle Subsidy, which are based on the Preferred Practice Guidelines for Prescribing Eye Glasses in Young Children from the American Academy of Ophthalmology, for anisometropia optical prescription in children four years and older, are 1.00D or more of hypermetropic anisometropia, 1.50D or more of cylindrical anisometropia, or 2.00D or more of myopic anisometropia. Therefore, these will be the clinical definitions for anisometropia used in this thesis.(57) Anisometropia is usually corrected with spectacles. However, spectacles with different optical powers may be problematic, as this will cause images on the retina to have different magnifications between the eyes, a phenomenon known as aniseikonia, which ought to be taken into consideration when prescribing optical correction, but only occurs on the occasions the anisometropia is greater than 4 dioptres.(79)
2.5.2 Strabismic Amblyopia

Another major cause of amblyopia is strabismus. Strabismus is a condition in which the eyes are misaligned. Normally, when looking at an object both eyes are directed towards that object. In strabismus, however, one of the eyes is not directed towards the object at which the patient is looking. Strabismus can affect either eye, and any direction of ocular movement. Strabismus is present in about 2-4% of children, and is more prevalent in older children than younger.\(^\text{80–82}\) Low birth weight and a positive family history are risk factors for strabismus.\(^\text{83}\)

Strabismus can either be manifest or latent. Manifest strabismus, given the suffix “tropia”, is when the deviation of an eye is present while the eyes are working together (or attempting to). Latent strabismus, given the suffix “phoria”, is when the deviation only occurs when binocular vision has been interrupted. Strabismus can also be grouped per the direction of the deviation. The deviation of an eye can be inwards, which is given the prefix “eso”, outwards, which is given the prefix “exo”, upwards, which is given the prefix “hyper”, downwards, which is given the prefix “hypo”, or rotational, which is given the prefix “cyclo”.

The most common type of strabismus in children is accommodative esotropia.\(^\text{84}\) This is usually associated with hypermetropia. When one changes their visual focus from a distance to relatively near, they can maintain focus via accommodation. Focussing on a near object requires output from the Edinger-Westphal nucleus, which responds with what is known as the ‘near triad’: lens accommodation, convergence of the eyes, and miosis.\(^\text{85}\) In the case of a child who is hypermetropic, they may be able to compensate their hypermetropia with accommodation, as their lens is relatively labile. However, this accommodation will result from the ‘near triad’, which also causes the eyes to converge unnecessarily, hence creating an esotropia.
Strabismus may also be caused by palsy or issue with the development of one or more cranial nerves innervating extra-ocular muscles, an issue with the extra-ocular muscles themselves, such as congenital fibrosis, an abnormality of the affected eye causing decreased vision, or trauma or infection to the globe or orbit. Strabismus is also associated with several congenital conditions such as Down syndrome, cerebral palsy, and Edwards syndrome. (86)

Strabismus may not have a significant effect on a child’s functional vision. In adults, strabismus can cause diplopia because a different image is being formed on the retina of each eye. However, in children the brain can ignore one of the inputs from an eye if the two inputs are significantly different, termed suppression. Thus, children with strabismus rarely complain of diplopia or any symptom of their strabismus.

This suppression eliminates the symptom of diplopia but causes cortical suppression of the image arising from the deviating, non-fixing eye. However, when this occurs during critical periods of development, it leads to inevitable consequences for the competitive visual development of each eye’s visual pathway, and can cause decreased stereopsis in children. (87) If a strabismic child has a strong preference for using one eye over the other for vision, the other eye may become amblyopic. Children with strabismus who also have alternate fixation tend to not develop amblyopia, since there is no long-term suppression of one eye. However, they may not develop normal binocular vision, as they do not use their eyes simultaneously.

Strabismus can also have lasting psychosocial impacts on patients, and it is thought to have a negative impact on many aspects of patient’s lives, including decreased self-esteem, employment, and relationships. (88,89) Strabismus is often easily identifiable to parents, even without screening, because it can be noticed cosmetically, as opposed to often inconspicuous refractive errors and other eye pathology. Clinically, strabismus is often diagnosed with a history and physical exam, including the use of corneal light reflexes and cover tests.
The treatment of strabismus will depend on its cause. Treatment of accommodative esotropia is usually by correcting the refractive error. Other types of strabismus may need to be corrected with surgery, which usually involves strengthening or weakening one or more extra-ocular muscles to correct the misalignment. Strabismus treatment offers great improvement in psychological and physical functioning. (90)

Strabismus is thought to account for around 19-25% of amblyopia cases. (2,91) Strabismic amblyopia is often less responsive to treatment than other forms. (49,92)

2.5.3 Deprivation Amblyopia

Deprivation amblyopia is amblyopia caused by an obstruction of the visual axis, due to an anomaly of any anatomical structure which may disrupt the path of light in the eye. Causes of deprivation amblyopia include ptosis, corneal scars, cataracts, aphakia or vitreous haemorrhage, or even over-aggressive occlusion therapy for treatment of amblyopia of the other eye. (2,93)

Obstruction of the visual axis of an eye of a child will mean that there will be a lower resolution of images on the retina, causing decreased foveal stimulation. This means there is less visual input to process, and so fewer neurons are recruited for visual activity. Eventually, if the visual input is sufficiently decreased, normal visual development is disrupted, and amblyopia can develop. Deprivation amblyopia accounts for about 3-9% of cases. (2,44,94) While rarer, the outcome for deprivation amblyopia is generally more severe than other types.

Deprivation amblyopia is treated firstly by correcting the underlying cause of the deprivation, then treating the amblyopia itself, if required.

2.5.4 Mixed Amblyopia
Amblyopia can also be caused by a combination of refractive error, strabismus, or deprivation, and this is thought to account for about 27% of cases.\(^{(2)}\)

### 2.6 Epidemiology of Amblyopia

Amblyopia is the most common cause of visual impairment in children, and the prevalence of amblyopia is variable between populations. It is usually reported as being between 1 and 5%\(^{(44,95–97)}\), but may differ based on the clinical threshold for diagnosis used in the study, the type of testing used, the training of the testers, and whether there is a population screening programme. New Zealand specific data, obtained from the Dunedin Multidisciplinary Health and Development Study (DMHDS), a cohort study following all children born in Dunedin in 1972-3, indicated that the prevalence of amblyopia, or having recovered from amblyopia, was 6.7%\(^{(98)}\).

There is thought to be no sex difference in prevalence of amblyopia\(^{(2)}\). Currently, there is little data on the prevalence of amblyopia in Maori or Pacific Island children in New Zealand, but children from more deprived backgrounds are at a greater risk of having amblyopia\(^{(99)}\).

### 2.7 Cortical Changes in Amblyopia

Amblyopia occurs secondary to an abnormality of the eye itself. However, the lesions of amblyopia have only been found to occur in the brain, and no evidence has been found which suggests there are changes to the retina in amblyopia\(^{(100,101)}\) Much of the current understanding of the neuroanatomical changes occurring in amblyopia stems from animal studies, particularly landmark studies from Hubel and Wiesel. Their studies often examined the brains of kittens, usually those which had an eye artificially impaired from birth, such as surgical occlusion or permanent deviation of an eye, mimicking the effect of an ocular occlusion in children\(^{(33,52,102)}\).
The main areas of the brain affected by amblyopia are the cells in the LGN and V1, which are receiving afferent information from the amblyopic eye. LGN cells driven by the amblyopic eye are smaller than cells driven by the better seeing eye, but these neurons are present in normal numbers and have a normal functional response. This suggests that the deficit in the LGN in an amblyopic patient is that the neurons here are participating in fewer geniculo-cortical connections, rather than the neurons being culled.(32,33) Amblyopic eyes tend to have a normal cortical magnification factor and an enlarged population receptive field sizes, as well as a disorganised spatial resolution and topography of neurons in V1, meaning that the visual system of the amblyopic eye is less adept at performing high acuity activities.(103)

### 2.8 Clinical Features of Amblyopia

The specific clinical features of amblyopia often depend on the timing of the abnormal visual experiences, and the cause of the amblyopia.(104) The main feature of amblyopia is a reduction in VA, usually unilaterally, and is thus often asymptomatic to the patient.(50) There are also several deficits, clinical and subclinical, in visual function in both the amblyopic eye and the fellow eye of amblyopic patients.(78)

The degree of loss of vision in patients with amblyopia is highly variable, and may be categorised as mild, moderate, or severe, a categorisation used by the Pediatric Eye Disease Investigator Group (PEDIG), a collaborative network for research in amblyopia and other paediatric ophthalmological conditions. PEDIG groups amblyopia in the following categories (table 1):

<table>
<thead>
<tr>
<th>Mild Amblyopia</th>
<th>VA of 6/9 to 6/12 in the amblyopic eye</th>
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<tbody>
<tr>
<td>Moderate Amblyopia</td>
<td>VA of 6/12 to 6/24 in the amblyopic eye</td>
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Severe Amblyopia

<table>
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<tr>
<th>Severe Amblyopia</th>
<th>VA of worse than 6/24 in the amblyopic eye</th>
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*Table 1: PEDIG Categories of Amblyopia Severity*

Around 25% of amblyopia cases would be classified as severe. (105)

Amblyopic patients have some degree of extrafoveal fixation, or eccentricity, and more severe cases of amblyopia tend to have a greater distance of fixation from the fovea. The fovea is the retinal location of a high density of cones, and is thus the area responsible for high visual acuity. Eccentric fixation is a sign of severe amblyopia, and often carries a poor VA prognosis. (106)

The crowding phenomenon is a physiological feature demonstrated by patients with amblyopia, whereby they demonstrate a worse VA when reading multiple optotypes than if reading single optotypes. This phenomenon can be elicited using crowding bars around optotypes, or vision-charts with multiple optotypes. The crowding phenomenon is due to the relatively large sensory-receptive field of the retina, which occurs in amblyopia, meaning there are fewer neurons being driven by the amblyopic eye, and thus each of those remaining neurons becomes innervated by a larger proportion of the photoreceptive area of the retina. The clinical implication of this is that eye charts using crowding bars can be more sensitive in the diagnosis of amblyopia, and thus should be used in clinical practice to not underestimate the severity of VA loss in amblyopia. (107)

Also, both stereoacuity and contrast sensitivity tend to be reduced in amblyopes. Stereoacuity is a measure of the smallest difference in depth that can be perceived, and is usually absent in strabismic amblyopia, and reduced in other types. (108) Contrast sensitivity is the ability to distinguish objects of different colours and brightnesses, and people with amblyopia will require more contrast to detect certain stimuli compared to those without amblyopia. (109)

### 2.9 Testing for Amblyopia
There are several ways to diagnose amblyopia, such as VA, stereoacuity, and contrast sensitivity. VA measurement is the most commonly used method, as it is readily available, as well as readily understood by most patients and examiners. Unlike other methods, it also requires minimal specialised equipment and is relatively portable. (43)

VA testing is a test of how well the visual system can resolve spatially distinct objects, and aims to determine the minimal angle where this resolution can occur, the minimal angle of resolution (MAR). Each optotype, usually a letter or figure, contains critical details: discrete components that must be discerned to allow identification of that optotype. VA can be noted in Snellen Fractions or in logMAR units. In Snellen Fractions, the denominator denotes the furthest distance at which the patient can identify the optotype (often 6 metres), and the numerator denotes the distance at which most people with normal vision can identify the same optotype, allowing an instant comparison of the patient with the normative values. VA can also be recorded in logMAR units, which is the logarithm 10 of the minimal angle of resolution, where the normal MAR is 1 minute of arc. logMAR units allow statistical analysis of VA scores that cannot be achieved with Snellen Fractions.

Visual acuity testing is ideally performed with optotypes surrounded by confusion bars which linearly decrease in MAR, and is high contrast, with black letters on white charts. Figure optotypes have an advantage over letter optotypes for paediatric patients who may be preliterate. (110) A range of visual acuity charts are used in clinical practice, and several examples are outlined below (table 2). The child may be asked to name the figure or letter shown, or, in younger children, asked to match the figure or letter shown to example figures/letters held by an assistant (often the child’s carer) before the child.

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<th>Allen Pictures</th>
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Stereoacuity can be tested with a stereogram, exposing each eye to two different panels of an image, by superimposing them with a stereoscope. If each eye is functioning normally, then the image should be perceived as having depth. In children, stereoacuity is often tested with the ‘Titmus fly test’, where a stereoscopic image of a fly is used, and if there is a sufficient level of stereoacuity, the observer can perceive the image through polarised glasses (of perpendicular axes) as three-dimensional, particularly the translucent wings of the fly.(111)

Contrast sensitivity can be measured by testing a patient’s ability to differentiate between increasingly similar contrasts. Individuals with reduced contrast sensitivity will require two points to have an increased difference in the level of the colour and brightness to be distinguished, compared to an individual with normal contrast sensitivity. Amblyopes have been found to have a reduced level of
contrast in both eyes, and so assessment of contrast sensitivity function may be useful in testing for amblyopia. (112)
2.10 Treatment of Amblyopia

2.10.1 Timing of Treatment

While most cases of amblyopia are treatable, this treatment must be within the critical period of visual development, before there are irreparable changes to the visual cortex. Earlier treatment of amblyopia has a better outcome due to the higher level of plasticity in the visual. (113) The plasticity of the cortico-visual centre in children diminishes as they age, and treatment is often ineffective in children once they are past around 9 years of age. (49) This means that earlier detection is important for the effective treatment, and suggests that the screening of amblyopia at the population level could be useful for providing timely treatment to patients. Earlier treatment also means that a shorter treatment duration is needed to achieve the same outcome. (41) However, there are cases of improvement in VA following treatment in older children, adolescents and adults with amblyopia after the classically taught critical period of visual development. (38, 114) This suggests that during the development of amblyopia neurons are suppressed rather than destroyed, and the visual system retains some plasticity. (48)

2.10.2 Treatment of Underlying Cause

The first principle of treatment of amblyopia is correcting the underlying cause. Refractive errors can be corrected with spectacles or contact lenses, strabismus can be treated by correcting any underlying refractive error, or correcting the misalignment with surgery, and media opacities should also be treated as soon as possible. Managing the underlying cause of amblyopia means that the disease is less likely to further develop, and subsequent therapy will be more efficacious. (115)
2.10.3 Penalisation therapy

The second aspect of amblyopia treatment is increasing usage of the amblyopic eye. This is achieved by suppressing the use of the 'better' eye, either via occlusion with patching, or by blurring it with the use of atropine drops, which acts to reverse the competitive developmental advantage that the non-amblyopic eye has had. Atropine works by limiting the ability for the better seeing eye to accommodate, so near-visual activity will be obligated to be with the amblyopic eye. Increasing use of the amblyopic eye will mean that there is an increased stimulation of the cortical areas associated with the amblyopic eye, which can help reverse the delayed development in the visual cortex. Occlusion therapy with patching of the better eye has been the mainstay of amblyopia treatment for many years.(116)

Some cases of refractive amblyopia may resolve with optical correction alone. However, occlusion therapy in conjunction with spectacles for refractive amblyopia has been found to be more effective than the use of spectacles alone.(115) The efficacy of both patching and atropinisation is comparable, and have visual acuity improvements of similar magnitude.(117,118) Atropine has the added advantage of being able to penalise the eyes of children who are not compliant with patching. Penalisation is effective in treating all three types of amblyopia.(119)

The duration of occlusion therapy is most effective within around the first 400 hours of occlusion. Full time and part time patching have similar outcomes, however, there is often a higher rate of compliance in children who have full time penalisation, since parents are less likely to forget during full time therapy.(120)

2.10.4 Outcomes of Amblyopia Treatment

Successful treatment can be achieved in up to 80% of patients, but the outcome is dependent on initial visual acuity, type of amblyopia, binocular status, level of
fixation, compliance and duration and timing of treatment.(100,106) While the rate of improvement of VA is slower for older patients than younger ones, there is little correlation of age at start of treatment with final visual acuity that can be achieved in amblyopia treatment.(105,121,122)

In general, children with combined-mechanism amblyopia may have a worse prognosis, even despite treatment.(122,123) This is probably because multiple causes will worsen the severity of the amblyopia. There is a strong correlation between the initial visual acuity and the best visual acuity that can be obtained from amblyopia treatment.(72,105) Treatment is worthwhile in children with severe amblyopia, but in cases of mild unilateral amblyopia there may be little benefit.(124). The PEDIG found that 2 hours of occlusion therapy for moderate amblyopia was just as effective as full-time occlusion, and improved VA to 6/9 in 62% of patients with moderate amblyopia.(116) The PEDIG also found that 6 hours of occlusion therapy was just as effective as full-time occlusion in severe amblyopia patients, and was able to improve VA by more than 4 lines on average in these cases.(125)

2.10.5 Adverse Effects of Treatment

While treatment can be associated with some distress to the child, there is often no effect on child’s well-being or behaviour during or after treatment.(126) Children with amblyopia who do not receive treatment are at risk of their VA deteriorating, or at least not improving on its own. A potential adverse outcome of amblyopia treatment is over-treatment, with too much occlusion of an eye. This can cause amblyopia in the patched eye, due to deprivation of that eye’s visual axis during the critical period over-suppressing development of the better-seeing eye. Therefore, it is important to monitor both eyes of a child undergoing amblyopia treatment.(127)
2.11 The Functional Impact of Amblyopia

An important and controversial topic is the functional impact of amblyopia. There are many studies which have examined this, and looked at long term outcomes of amblyopia in factors such as motor skills, psychological functioning, education, employment, and socio-economic status (SES). (98,128,129)

Vision is an important sensory stimulus for a developing child. Amblyopia, with its unilateral visual impairment, could possibly hinder the development of other complex functions in children, such as motor development. It may affect the acquisition of skills such as grasping, hand-eye coordination, walking, and balance. It has been found that children with amblyopia may have a reduction in some fine motor skills, compared to normal children, particularly in tasks that require speed and accuracy. (45,130) Monocular vision in otherwise normal individuals is also associated with a decrease in perception of velocity, increased reaction time, and worse at performing prehensile actions compared to those with binocular vision, suggesting that amblyopia may lead to issues with motor skills. (100,129)

Also, amblyopes have been found to have a slower reading speed than non-amblyopes, but this did not necessarily correlate to a difference in academic achievement. (129) There is some evidence that amblyopia has a significant effect on psychosocial functioning, with difficulties relating to an individual’s self-image, work, school, and friendships. (130,131) However, amblyopia is thought to not impact on lifetime occupational class. (3)

A study arising from the DMHDS found that people with amblyopia or having recovered from amblyopia had no difference in motor skills in children, self-esteem in adolescence, or socio-economic status and education in adulthood. This suggests that amblyopia may not have such adverse outcomes on the day to day lives of patients. (98)

An important consideration with amblyopia is that if an amblyope loses vision in their better-seeing eye, such as from trauma or other eye pathology, they will have low vision in both eyes. This is far more disabbling than the otherwise unilateral
vision loss that would occur in someone with normal vision losing vision in one eye. Amblyopes are at an increased risk of vision loss in their better eye, where the risk may be as much as three times greater. More than half of the causes of visual impairment in the better eye is trauma. A possible reason for this increased risk in amblyopes is that there are subclinical cortical deficits and visuo-cortical instability of the better seeing eye, and so the ‘normal’ eye may be at more susceptible to injury.

While there is a risk of bilateral visual impairment in amblyopes who lose vision in their better-seeing eye, a study has found that 10% of people with amblyopia who had lost vision in the better eye had a significant improvement in the VA of their amblyopic eye. The mechanism for this is not fully understood, but does suggest that the visual pathway in some people may retain the ability to adapt long after the critical period in childhood.
Chapter Three - Childhood Vision Screening

3.1 What is Screening

Screening is a process to identify medical conditions in a population who may be asymptomatic, identifying individuals who have a condition in its early stages, before it would otherwise become apparent. Screening allows earlier intervention than would otherwise be possible, which usually leads to better health outcomes. Screening tests are not intended to be diagnostic, but instead identify those who are likely to have the disease to help guide further investigations.

3.2 Validity of Screening

The result of a single screen is either positive, i.e. the patient is suspected to have the disease, or negative, i.e. the patient is expected to not have the disease. This presents four possible outcomes of a single screening test: truly positive (TP), falsely positive (FP), truly negative (TN), or falsely negative (FN).

Sensitivity is the measure of how likely that those who have the disease will have a positive screen. A high sensitivity means that cases of the disease are less likely to be missed.

\[
Sensitivity = \frac{TP}{TP + FN}
\]

Specificity is the measure of how likely that those who do not have the disease will have a negative screen. A high specificity means that there will be fewer of people without the disease having positive screens.

\[
Specificity = \frac{TN}{TN + FP}
\]
Positive Predictive Value (PPV) is how likely an individual who is screened as positive will have the disease.

\[
PPV = \frac{TP}{TP + FP}
\]

Negative Predictive Value is how likely an individual who is screened as negative will not have the disease.

\[
NPV = \frac{TN}{TN + FN}
\]

Screening programmes with high sensitivity, specificity, PPV, and NPV are more reliable, and will have fewer cases of false screening results.

### 3.3 Requirements for a Screening Programme

Not all medical conditions are suitable candidates for population screening programmes. In 1968, Wilson and Jungner described 10 principles for screening programmes in their work *Principles and Practice of Screening for Disease*, which are outlined in the textbox below, and have become widely used to guide the implementation of population screening programmes throughout the world.(134)

1. The condition should be an important health problem
2. There should be an accepted treatment for the condition
3. There should be facilities for diagnosis and treatment available
4. There should be a latent stage of the disease
5. There should be a suitable test or examination for the condition
6. The test should be acceptable to the population
7. The natural history of the disease should be adequately understood
8. There should be an agreed policy on whom to treat
9. The total cost of finding a case should be economically balanced in relation to total medical expenditure
10. Case-finding should be a continuous process, not just a “once and for all” project
These principles have been widely considered the standards for judging screening tests. (135)

### 3.4 Why There Should be an Amblyopia Screening Programme in New Zealand

Many societies, including New Zealand, have adopted some form of childhood vision screening for the detection and treatment of amblyopia. Amblyopia is generally asymptomatic and requires treatment during the critical period of visual development. A potential screening programme disease should meet the principles outlined by Wilson and Jungner to be implemented, and thus these principles, as applied to amblyopia, are outlined below.

#### 3.4.1 Amblyopia as an important health problem

Important health problems include conditions with a high prevalence, as well as presenting severe enough consequences to the individual or community. Incredibly rare or rather mild disease are therefore not necessarily suitable for screening programmes. Amblyopia is an important and relatively prevalent health problem: it is most common cause of unilateral visual impairment in the first four decades of life. Of note, however, the functional impact on an untreated individual later in life is perhaps less certain, as described previously. Nonetheless, amblyopia can have a major effect on a patient’s vision if they also have vision loss in the better-seeing eye later in life, leaving only an amblyopic eye for vision.

#### 3.4.2 Accepted Treatment of Amblyopia

It is neither ethical nor a prudent use of resources to screen for diseases which are not able to be treated. Also, the treatment for a screened disease should be
more effective during the pre-symptomatic, border-line stage than in its late stages, to justify the need to treat the disease sooner.

Amblyopia is treatable, treated by correcting the underlying cause of the amblyopia, and with penalisation of the better eye, with patching or atropine, often with positive results. This therapy must occur before the critical period of visual development. This suggests that detecting cases by screening can allow earlier, and thus more efficacious, treatment.

### 3.4.3 Facilities for Diagnosing and Treating Amblyopia

If a society is to adopt a population screening programme, it must have the resources to treat all cases of the disease detected through screening: it is not ethical to invest in screening programmes when there is no follow-up for suspected cases. Many health professionals can diagnose and treat amblyopia, including nurses, general practitioners, optometrists, orthoptists, and ophthalmologists.

### 3.4.4 Latent Stage of Amblyopia

If a disease is to be screened it should have a latent stage, where symptoms are not present, but the disease is still able to be detected if it is specifically tested. If the first indications of a disease are symptoms, patients and clinicians will be aware there is a disease regardless of the screening. Amblyopia is a developmental disorder, and during earlier stages of the disease symptoms are milder, and thus has a period of latency. If left untreated, the severity of amblyopia can worsen, and the ability to treat diminish.

### 3.4.5 Suitable Test for Amblyopia

Screening tests need to have an acceptable level of validity to be able to find cases of the disease, and rule out those which are not likely to be cases of the
disease. This means minimising the number of FP, so that fewer patients are subjected to unnecessary investigations and worry, and minimising the number of FN, so that fewer cases of disease are missed and fewer patients have a false sense of security.

There are several ways of testing for the presence of amblyopia. The clinical features of amblyopia include reduced VA, reduced CS, and reduced stereoacuity, and measurement of these could be used to identify potential cases of amblyopia. VA testing is useful, as it is portable and relatively easy to perform, even without significant training, and is thus the preferred method of screening for most populations.

However, a range of factors may affect VA testing, such as lighting, type of test chart, distance from the chart, and experience of the examiner, and these may influence the accuracy of the test, which means that there may be a relatively high proportion of falsely positives and falsely negative results from the screening.\(^{(136,137)}\) There is a tendency for many paediatric vision screening tests to have a large proportion of false positive results, possibly because children may be uncooperative or easily distracted, meaning that a lot of children are detected as having amblyopia in screening, but turn out to not have anything wrong with their vision.\(^{(138–140)}\) This can mean there are financial costs with health care professionals seeing patients unnecessarily, and opportunity costs of other patients possibly being delayed in accessing those health care professionals.

### 3.4.6 Acceptability of Amblyopia Screening to the Population

A test in a screening programme needs to be acceptable to the population to which it is offered. This requires the population having an adequate education about the disease, and the testing not being too discomforting or upsetting to the population. A screening test should be quick and easy to perform, and minimise discomfort to the patient. Screening tests that difficult or distressing to the patient may not be well tolerated by the population. Most vision screening consists of
measuring VA, which is not particularly distressing to most patients, including children. Most parents/caregivers are also aware of the importance of vision, and are happy for their children to participate in a vision screening programme.

### 3.4.7 Natural History of Amblyopia

It is important to understand how a disease progresses and what effect it can have, so that the detection of early signs in screening can be accurately correlated to the later, symptomatic stages. Most knowledge about the natural history of amblyopia comes from animal models, and there has been little research directly assessing the natural history of amblyopia, due to ethical concerns. However, once the critical period is reached and if the disease not treated, the severity of the visual acuity loss usually stays the same.

### 3.4.8 Agreed Policy on Amblyopia Diagnosis and Treatment

For a screening programme to function properly, there needs to be clear guidelines on what cases should receive further investigations or treatments. If clinicians have differing protocols for when to treat the same condition, some cases identified in screening may or may not be treated, depending upon the preferences of a patient’s clinician.

As there is a range of clinical definitions of amblyopia, including differing levels of VA which constitute amblyopia, a screening programme would need to adopt a fixed criterion for which patients will be screened as positive, for example, a VA of 6/9 in one eye.

High quality evidence exists for the treatment of amblyopia using penalisation therapy, and this forms the basis for evidence-based practice by treating orthoptists, optometrists, and ophthalmologists. However, treatment of
amblyopia will still depend on the clinician’s clinical judgement, and there is no set
guideline for this in New Zealand.

3.4.9 Cost-effectiveness of Amblyopia Screening

If screening can significantly increase a society’s economic situation, or avoid
huge economic cost, then this is a good thing. However, if the cost of screening
proves to be more expensive than the disease would be, the economic benefit of
screening is questionable. The cost of finding a case of amblyopia should be
weighed in relation to the economic cost of a case of amblyopia itself. Costs
associated with a vision screening programme include the employment of those
administering the screening, including salary and transport, as well as the cost of
management and administration of the screening programme.

As most cases of amblyopia feature a unilateral reduction in vision of one eye,
the cost of a higher prevalence of amblyopia in society largely depends on the long-
term effect of this unilateral vision loss, which, as discussed, may not have such a
significant impact on the individual’s functioning. Also, if a vision screening
programme is not completely accurate and has a large proportion of false positive
and false negative results, then the screening is not maximising the number of
cases of amblyopia it is detecting, and may be expending too many resources in
referral pathways for ‘normal’ patients.

Thus, while treatment of amblyopia is considered effective, the cost
effectiveness of vision screening and treating a case of amblyopia is still
controversial, and so several studies have analysed the cost-effectiveness of
amblyopia screening, comparing the cost to the Quality-Adjusted Life Years (QALY)
gained. A National Health Service review in the United Kingdom (UK) into the cost-
effectiveness of amblyopia screening in the UK for children aged between 4 to 5
years found that screening is not likely to be cost-effective at accepted values of a
QALY, compared to other screening programmes. (142) A study of vision screening
cost-effectiveness in Germany indicated that the cost of finding one case of
amblyopia ranges from about USD $650-1630. (143) Another study in the United States in 2012 found that VA and stereoacuity screening of children in kindergarten had a cost of USD $17,000-21,000 per QALY gained, and while being comparable in cost to multiple other public health programmes, was also found to be less cost-effective than no amblyopia screening at all. (144)

3.4.10 Amblyopia Screening as a Continuous Process

Screening needs to be happening continuously. Without continual screening, only the small population who is screened will receive the benefits of screening, and thus the screening will not affect the future incidence. Also, continuous screening allows the screening organisation to become more efficient and proficient.

A population vision screening test can be performed on each target demographic multiple times at different ages, and for different groups continually over time, so that the screening can be a continuous process.

3.4.11 Suitability of a Screening Programme for Amblyopia

One might think that a disease like amblyopia, where timely treatment is paramount to the success of the treatment, where it is relatively common in society, but without patients presenting with symptoms, and where there may be associated effects to the development of a child with amblyopia, would be an ideal candidate for a public health screening programme. Indeed, an amblyopia screening programme appears to meet many of the screening programme guidelines outlined by Wilson and Jungner: amblyopia is treatable and there are facilities to treat it, it has a latent stage, there are suitable tests for screening, testing is acceptable to the population, the natural history of it is understood, there can be an agreed policy on whom to treat, and the screening can be a continuous process.
However, there is still debate in literature regarding paediatric vision screening, and there is substantial support of discontinuing many vision screening programmes.\(^{(145-148)}\). The controversy surrounding amblyopia screening programmes largely stems from the uncertainty of how much of a public health issue and economic burden the disease is, and whether is it severe enough to warrant a screening programme for it, the uncertainty of how well a vision screening programme can reliably and accurately detect cases of amblyopia (and cases of normal vision), and the uncertainty of how cost-effective the endeavour of screening truly is. If a society is going to have a population screening programme for amblyopia, it should ideally address these issues first, and therefore there needs to be more research into these areas.

### 3.5 When to Screen for Amblyopia

Childhood vision screening needs to occur before the critical period of visual development, meaning all cases should ideally be identified before 7 years of age, for treatment to be effective. However, if screening occurs too early vision testing will be more prone to performance artefact, and there is a risk of missing cases of amblyopia that may develop after the screening. It has been suggested that the optimal age for screening for strabismic amblyopia is 12-18 months.\(^{(92)}\) However, screening all high-risk children up to the age of one year only identifies about one third of amblyopia cases.\(^{(143)}\)

One study found that children being treated for amblyopia are four times as likely to remain amblyopic if they are only screened at 37 months, compared to those screened both at 8 and 37 months, which suggests that multiple screening may optimise detection of amblyopia cases.\(^{(149)}\) It has also been found that children screened for amblyopia at 5 years of age did not have a reduced potential for improvement compared to children screened at younger ages.\(^{(150)}\) Screening around this age would be a good compromise, as it allows sufficient time to treat
amblyopia, while also being late enough to minimise the number of cases missed or developing after screening.

### 3.6 How to Screen for Amblyopia

Amblyopia usually features a unilateral reduction in VA, and so one obvious way to screen for amblyopia is by measuring the VA of each eye with an eye chart. This method of testing is relatively simple, and can be administered by people without necessarily needing advanced training. Other advantages of VA testing include it being relatively well understood and accepted by the general population.

It has been suggested that childhood vision screening should include the use of autorefraction alongside VA testing, to allow the detection of suspected refractive error as well, such as high hypermetropia, which may not present with a decreased VA, as the child is still able to accommodate, but can cause other visual problems later.\(^\text{(110)}\)

Another method of childhood vision screening is photoscreening, with the use of a photoscreener, a non-invasive device that takes images of a patient’s eyes, and can measure refractive state, the pupil size and distance, and the gaze deviation. Advantages of photoscreening include it being quick and easy to perform, with the patient only needing to be attentive for a few seconds. However, there are several disadvantages, such as it being a relatively expensive piece of equipment, and often needing a trained specialist to interpret some of the results. Photoscreening may be a cost-effective way of population screening, and some photoscreeners have relatively high levels sensitivity and specificity, for example the Plusoptix Vision Screener (Plusoptix, Germany), which has a sensitivity of 98%, and a specificity of 69%.\(^\text{(151)}\) These types of devices may allow the detection of amblyopia risk factors, without needing an ophthalmologist to administer the exam.\(^\text{(152,153)}\)

Other methods of amblyopia screening include measuring optokinetic nystagmus and Visual Evoked Potentials. Using these tests as a part of a screening programme do present some issues as they are usually more difficult to administer, and have less test-retest reliability than VA testing. \(^\text{(154,155)}\)
3.7 Examples of Societies with Some Form of Vision Screening

Following Hubel and Wiesel’s elucidation of the development of amblyopia, many populations adopted and have continued to practise some form of vision screening. Several examples of societies with childhood vision screening programmes, and the methods used for screening (table 3).(156)

<table>
<thead>
<tr>
<th>Country (State)</th>
<th>Method of Screening</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia (New South Wales)</td>
<td>VA in 4 year olds with 6m linear chart (157)</td>
</tr>
<tr>
<td>Australia (Victoria)</td>
<td>VA in 3.5 year olds with letter matching at 3m (158)</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>VA in 4-5 year olds with linear chart (159)</td>
</tr>
<tr>
<td>United States of America (California)</td>
<td>VA testing at 5 years with linear chart at 6m (160)</td>
</tr>
<tr>
<td>Japan</td>
<td>VA testing at 3 years with Landolt ring at 2.5m at home (161)</td>
</tr>
<tr>
<td>Sweden</td>
<td>VA testing at 4 years HOTV chart at 3m (162)</td>
</tr>
</tbody>
</table>

Table 3: Societies with and Methods of Childhood Vision Screening

There are several countries that do not have a standardised national vision screening programme, such as Canada, Spain and Switzerland.(156) Also, there are different vision screening programmes in use in Australia, between various states and territories, which do lack coordination and national guidelines on when and
how to screen. A lack of consensus does mean it is both difficult to analyse the efficacy of this screening, and there may be a significant number of children not being screened, as providers of various screening programmes are not aware of which children have already been screened elsewhere. (163)

The United Kingdom national guidelines suggest using an orthoptic led screening programme to detect visual impairment in children aged 4 to 5 years, and this has been found to be accurate, with a positive predictive value of 86%. (164) Vision screening in Germany has been found to have a sensitivity and specificity of an orthoptic led screening programme was 90.9% and 93.8%. (165) Both cases imply that screening for reduced VA in children carried out by eye care professionals may allow for high levels of accuracy, compared to other health professionals. It has also been found that in Israel the prevalence of amblyopia in a screened population was 1.0%, compared with the prevalence of amblyopia in an unscreened population of 2.3%, suggesting that screening does indeed reduce the amount of amblyopia in a population. (166)

In the Netherlands, a large prospective study, following a cohort of 3000 children from birth, found that only around half of those children with amblyopia were identified by the vision screening programme. This suggests that vision screening may not be hugely sensitive, and raises further questions over its reliability. (167)
3.8 The B4 School Check

The first part of childhood vision screening in New Zealand occurs through the B4 School Check. The B4SC is a nationwide programme aimed at screening for a range of health issues in children before they reach school, such as vision, hearing, and development. The purpose of the vision screening is to identify any children who have amblyopia, at an age where it is still treatable.

Vision screening is administered by vision hearing technicians (VHTs): trained personnel who undergo continued professional development, as well as routine assessment of competence. These VHTs work in the community to screen children for vision and hearing problems, usually once the child turns 4, and ideally before the child’s 5th birthday. The screening often occurs in a school or kindergarten, but may occur at the child’s home if necessary.

The B4SC guidelines for vision screening (appendix A) employ VA testing with Parr Letter matching, with confusion bars, at 4 metres. The B4SC vision screening is identifying children with decreased VAs, which may result from amblyopia, refractive error, or other eye pathology, and thus, analysis of the accuracy of the testing of the B4SC vision screening programme should consider all causes of low vision as a true positive referral.

The threshold for a positive screen, resulting in a referral, is a VA of 6/12 or worse in either or both eyes. A VA of 6/9 in one eye and 6/6 in the other will result in repeating the screening a later date. If there is a decrease in VA, or no improvement on rescreening, then that child will be referred. If the screening result from the rescreen is 6/6 in each eye, that child will pass the screening.(42) The possible post-screening referral pathway is outlined below (fig. 5).
Figure 5: Referral pathway for the B4SC

3.9 Efficacy of the B4SC

For the B4SC to be optimal in detecting vision defects in a population, it must screen most, if not all, of the population, as well as the testing being accurate, meaning there will be very few cases of undiagnosed amblyopia in the community, and there are very few instances of people being falsely screened as having amblyopia.

There has been one review into the efficacy of the B4SC vision screening, by Langeslag-Smith, who studied the programme in Counties-Manukau DHB.(168) This study, looking at all children who failed vision screening in one year, found that screening produced high numbers of false positive referrals, resulting in a positive predictive value of only 31%. This suggests that the VHTs are likely to over-refer, when there may not be a vision problem. This may be due to the training of the VHTs, the Counties-Manukau population including a large proportion of international children who may not necessarily be able to
communicate well with the VHTs, as well as the nature of testing 4-year-olds, who may not comply with the vision screening, or may otherwise interfere with the screening process. The implication for this high PPV is that the B4SC is more costly and inefficient than it otherwise could be, since it is referring many ‘normal’ children into eye care services. Optimised efficiency of vision screening would mean fewer unnecessary referrals to DHBs and optometrists, which could lower health care costs, and help unburden already stretched services.

The negative predictive value found in this study was 92%, which is high enough to suggest that most cases are detected. This value was calculated in a sample of children who were referred from the B4SC to the DHB eye clinic, and were found to have a reduced VA in one eye, but compared to the VA values from the eye with a normal VA to the B4SC VA result for that eye. It was noted, however, that altering the criteria for a positive screen from a VA of 6/9 in either eye to 6/12 would improve the PPV, without adversely affecting the NPV, meaning that altering the B4SC criteria to only refer children with 6/12 or worse in either eye could reduce the number of false positive referrals, which would be a cost-effective change.(168)
Chapter Four - Aims

4.1 Primary aim

1. To determine the false positive, false negative, positive and negative predictive values of the childhood vision screening component of the B4 School Check in Southern and Tairawhiti DHBs for amblyopia and/or refractive error.
   - Where amblyopia and/or refractive error are defined as a visual acuity of 6/9 or worse in at least one eye, or 6/12 or worse in both eyes
     - [This definition selected to match the criteria that will result in a referral for further optometric/ophthalmic examination by the B4SC Vision Screening Program.]

4.2 Secondary aims

1. To determine the prevalence of amblyopia and/or refractive error in 4-7 year old children in Southern and Tairawhiti District Health Boards
2. To describe the causes of amblyopia and nature of refractive errors in 4-7 year olds in Southern and Tairawhiti DHBs
3. To compare and contrast the incidence of amblyopia and/or refractive error between Southern and Tairawhiti DHBs, including analysis of possible relationships with ethnicity and socio-economic deprivation.
4. To determine the post-referral pathway of children who fail the vision screening component of the B4SC
   a. Choice of and attendance at an eye healthcare provider
   b. Management of amblyopia and/or refractive error
5. To describe the characteristics of children diagnosed with amblyopia and/or refractive error without referral from the B4SC programme.
Chapter Five - Methods

This study was a retrospective audit, and analysed the children who had been screened for vision between 1 April 2016 and 30 September 2016, by the B4SC, in both the Southern and Tairawhiti DHBs. A referral from the B4SC vision screening programme, which is defined as a VA of 6/9 or worse in one eye, or 6/12 or worse in both eyes, can lead to follow up assessment with either an optometrist, local DHB eye clinic, or a private ophthalmologist. Data from the B4SC was compared to data collected from Southern and Tairawhiti DHB eye clinics, and to data collected from community optometrists in the Southern and Tairahwhiti regions.

Clinical data was obtained from three sources:

- B4 School Check database.
- Clinical records of Southern and Tairawhiti DHB eye clinics.
- Community optometrists in the Southern and Tairawhiti DHB regions.

5.1 Inclusion Criteria

All children screened for vision by the B4SC in either Southern or Tairawhiti DHB, between 1 April and 30 September 2016, as well being seen at either:

- a community optometrist between 1 April and 31 October 2016 or,
- a DHB eye clinic in SDHB or TDHB between 1 April and 30 November 2016.

5.2 B4SC database

Information on children who were screened for vision with the B4SC in Southern and Tairawhiti DHBs was collected from the Ministry of Health. Only the identifying information (i.e. name, date of birth, and NHI number), date of the
screen, and the results of the screen (i.e. pass, fail, or rescreen) were collected.

Of the children screened within the study period and meeting the criteria for inclusion (by presenting at a community optometrist or DHB eye clinic) the following additional information from the Ministry of Health B4SC Database was collected:

- Ethnicity
- Gender
- Visual acuity of right and left eyes from screening
- Referral status
- Any follow-up data from referrals

5.3 Southern and Tairawhiti DHB clinical records

Clinical records of all children aged 4-7 years seen at Southern and Tairawhiti DHBs (Southland, Dunedin and Gisborne Hospitals) between 1 April and 30 November 2016 were collected. This longer data collection period was to allow for the delay between referral from the Vision Hearing Tester and First Specialist Assessment (FSA) at the relevant hospital.

A list of children aged 4-7 who had been seen during the study period was created using patient management software, and their NHI number was recorded. Patient notes were then collected for the appropriate children. From the patient notes, the following information was recorded:

- Name
- NHI
- DOB
This information was used to crossmatch children to the list of those screened from the B4SC database. Children seen at Southern and Tairawhiti DHBs who were screened by the B4SC programme between 1 April and 30 September 2016 were de-identified and the following additional clinical information from the patient notes was recorded:

- Source of referral where applicable (e.g. VHT, GP, optometrist, DHB)
- Visual acuity of each eye
  - Unaided and Best Corrected as applicable
  - Specifying which visual acuity test used
- Cause of visual impairment (if any)
  - Refractive error
  - Amblyopia
    - Strabismic, pattern deprivation or refractive
  - Ocular pathology
- Ophthalmic examination findings
  - Cycloplegic refraction
  - Ocular pathology
- Management
  - Glasses
  - Penalisation
  - Surgery
  - Discharge
  - Observation

No further information regarding children seen at Southern and Tairawhiti DHBs who were not screened by the B4SC programme between 1 April and 30 September 2016 was collected, and their records were deleted from the study’s database.
5.4 Community optometrist clinical data

We approached and engaged with local community optometrists in Otago, Southland, and the Gisborne area. Clinical data regarding all children aged 4-7 years seeing an optometrist between 1 April and 31 October 2016 was recorded. This longer data collection period was to allow for the delay between referral from the Vision Hearing Tester and the arrangement of an appointment with an optometrist by the child's parent or caregiver.

There were several methods used to collect data from community optometrists. Practices either regularly emailed clinical records with the appropriate information as relevant children were seen, filled in copies of the optometrist data sheet (appendix B) to be collected by the student researcher, or recorded a list of names of children who had been seen, and allowed the student researcher to review their notes, depending on practice resources and clinician preference.

In each case, the following information was recorded:

- Demographic details
  - Name
  - DOB

This information was then used to crossmatch children to the list acquired from the B4SC database. Children seen by an optometrist who were screened by the B4SC programme between 1 April and 30 September 2016 were de-identified and the following additional clinical information was recorded:

- Date of appointment
- Source of referral (e.g. VHT, parent, GP)
- Visual acuity of each eye
- Unaided and Best Corrected as applicable
- Specifying which visual acuity test used
- Cause of visual impairment (if any)
  - Refractive error
  - Amblyopia
    - Strabismic, pattern deprivation or refractive
  - Ocular pathology
- Ophthalmic examination findings
  - Cycloplegic refraction where possible
  - The presence of any pathology
- Management
  - glasses
  - penalisation
  - ophthalmology referral
  - discharge
  - observation

No further information regarding children seen at their optometrist who were not screened by the B4SC programme between 1 April and 30 September 2016 was collected, and their clinical records were deleted from the study's database.

5.5 Variables

The variables measured this study were:

- Screening Outcome from B4SC (pass, fail, or rescreen)
- B4SC tested VA in the left and right eyes (logMAR)
- Optometrist, DHB, or private ophthalmologist tested VA in the left and right eyes (logMAR)
- Presence of amblyopia (defined as logMAR > 0.3)
- Presence of refractive error
5.6 Data analysis

Identifying details of all children included in this study were cross-matched between data sources (B4SC, DHB, and optometry practices), for both Southern and Tairawhiti DHBs. Subsequent data analysis was only be performed on children screened by the B4SC programme between 1 April and 30 September 2016 in Southern and Tairawhiti DHBs, utilizing data available from all sources as collected above.

All visual acuity scores were converted to logMAR units for statistical analysis. Descriptive statistics of all data variables were calculated for each data source, to allow the estimation of the proportion of screenings resulting in referral, as well as estimation of prevalence of amblyopia, refractive error, and other ocular pathology in the study population.

Visual acuity scores obtained from the B4SC vision test were compared to visual acuity results from DHB eye clinics and optometrist assessments, for all pooled data, and for data stratified DHB, gender, ethnicity, geographical location, screening result, and diagnosis. Since the optometrist and DHB measurement of visual acuity is the ‘gold standard’, the B4SC data was compared to the ‘gold standard’ VA data with a two-sided paired t-test. The mean error of the B4SC VA results was also plotted against the optometrist/DHB obtained VA, to determine whether there is any bias within the distribution of error.

Sensitivity and specificity, as well as positive and negative predictive values was calculated per DHB and from pooled data. This was done by determining the
numbers of true positives, true negatives, false positives, and false negatives of the B4SC screening, in children seen at a DHB eye clinic, optometrist, or private ophthalmologist. Using published rates of amblyopia and refractive errors in comparable populations, the total prevalence of amblyopia in the B4SC screened population was determined.

This allowed an estimation of the number of cases of amblyopia in the group of children screened but not seen at a DHB eye clinic, optometrist, or private ophthalmologist. Using a best-case scenario (i.e. all undetected cases of amblyopia belong to the children with a positive screen but no further follow-up) and a worse-case scenario (i.e. all undetected cases of amblyopia belong to children who passed the screening and were not seen), we were able to calculate the sensitivity, specificity, positive and negative predictive values of the B4SC vision screening, for best and worst-case outcomes, giving a range of values in which the true values lie.

B4SC referral rates and optometrist/DHB diagnoses of amblyopia and ophthalmic diagnoses were analysed according to ethnicity, comparing pooled, intra- and inter-DHB means descriptively and using Pearson’s chi-squared test where ethnicity index category sample sizes permitted.

5.7 Ethics and informed consent

Institutional review board approval for this study was obtained from the University of Otago (Health) Research Ethics Committee. Specific informed consent for participation in this study was not required to be obtained from children’s caregivers for this retrospective audit activity.
Chapter Six - Results

6.1 The Study Population

This study identified and collected demographic data (name, date of birth, and NHI) for 958 children aged between 4 and 7 years who were seen at Southern and Tairawhiti DHB eye clinics between 1 April and 30 November 2016 and community optometrists between 1 April and 31 October 2016, in both the Southern and Tairawhiti DHB catchment areas. This comprised 744 children from SDHB region (396 seen at SDHB, 348 seen at SDHB region optometrists) and 214 children from the TDHB region (22 seen at TDHB, 192 seen at TDHB region optometrist).

There was a total of 99 of these children who also underwent vision screening as part of the B4SC between 1 April and 30 September, and thus eligible for inclusion in this study (53 in SDHB, 46 in TDHB). In the SDHB, 22 children were seen at an optometrist as well as screened for vision by the B4SC, and 31 children were seen at the DHB eye clinic as well as screened. In the TDHB, 46 children were seen at an optometrist as well as screened for vision by the B4SC, 1 of whom was also seen at the DHB eye clinic. The numbers of children identified through optometrists and DHB eye clinics, the numbers of children screened by the B4SC, and the numbers of children receiving both, in the SDHB, TDHB, and combined, are shown below (fig 6-8).
Figure 6: Numbers of Children Seen at Optometrists, DHB eye clinics, and B4SC in SDHB

Figure 7: Numbers of Children Seen at Optometrists, DHB eye clinics, and B4SC in TDHB
6.2 Collection of Data

6.2.1 Optometry Data

Optometry practices in the SDHB and TDHB areas were identified and asked to participate by noting clinical records of the relevant children seen at the practice. In the SDHB, 21 optometry practices were identified and approached, all of which initially agreed to participate. The practices were in Dunedin, Invercargill, Queenstown, Wanaka, Oamaru, and Te Anau. Complete records were obtained from 17 practices in the SDHB, partial records between June and October 2016 were obtained from 1 practice due to software issues, and 3 practices were not able to supply data. The relative numbers of children aged 4-7, who were also screened for vision by the B4SC, seen at the practices that did supply their clinical records are shown (fig. 9).
Three of the practices in SDHB offer a free optometry assessment for children. The bars in blue represent practices that see children for free for the child’s first visit. The red bar represents the practice from which partial records were obtained, which also happened to offer free assessment to children.

In TDHB, three optometry practices were identified and approached, all of which agreed to participate and supplied complete records; all were in Gisborne. The relative numbers of children aged 4–7 seen at these practices, who were also screened for vision by the B4SC are shown (fig. 10). One practice offers free optometry assessment to children (blue in graph).
6.2.2 DHB Data

Data from DHB eye clinics was obtained by identifying relevant children from patient management software and collecting from their clinical records. The Southern DHB provides eye clinics in Dunedin Hospital (Dunedin) and Southland Hospital (Invercargill). Dunedin Hospital reviews children referred from the B4SC within four months of referral, usually by an orthoptist. Southland Hospital Eye Department does not take referrals directly from the B4SC, as they are required to be reviewed by a community optometrist first for their referral to be accepted. There were 31 children in the study who were seen at a SDHB DHB eye clinic, all of whom were seen at Dunedin Public, none at Southland Hospital.

In TDHB, the DHB eye clinic is located at Gisborne Hospital (Gisborne). Gisborne Hospital eye department also does not take referrals directly from the B4SC. There was one child in the study seen at the TDHB eye clinic, who was also seen in the study period at a community optometrist.
### 6.3 B4 School Check Outcomes

The numbers of children who were eligible for and were screened for vision by the B4SC between 1 April and 30 September 2016, and the numbers of those children who were also seen at a local optometrist between 1 April and 31 October 2016 or at a DHB Eye Clinic between 1 April and 30 November 2016, at the SDHB, TDHB, and combined, respectively, are shown below (tables 4-6).

<table>
<thead>
<tr>
<th></th>
<th>Number of Children (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eligible for Screening</td>
<td>1942 (100)</td>
</tr>
<tr>
<td>Under Care of Eye Health Professional at time of Screening (thus not screened)</td>
<td>54 (2.8)</td>
</tr>
<tr>
<td>Received Screening and not Already Under Care</td>
<td>1739 (92.1)</td>
</tr>
<tr>
<td>Failed Vision Screening</td>
<td>134 (7.7)</td>
</tr>
<tr>
<td>Failed and seen at optometrist or DHB eye clinic</td>
<td>43 (32.1)</td>
</tr>
<tr>
<td>Failed and not seen at optometrist or DHB eye clinic</td>
<td>91 (67.9)</td>
</tr>
<tr>
<td>Passed and seen at optometrist or DHB eye clinic</td>
<td>10 (0.6)</td>
</tr>
</tbody>
</table>

*Table 4: Number of children in the SDHB eligible for B4SC Vision Screening and the main outcomes of this screening*

<table>
<thead>
<tr>
<th></th>
<th>Number of Children (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eligible for Screening</td>
<td>402 (100)</td>
</tr>
<tr>
<td>Under Care of Eye Health Professional at time of Screening (thus not screened)</td>
<td>26 (6.5)</td>
</tr>
<tr>
<td>Status</td>
<td>Number of Children (%)</td>
</tr>
<tr>
<td>-----------------------------------------------------------------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>Received Screening and not Already Under Care</td>
<td>370 (98.4)</td>
</tr>
<tr>
<td>Failed Vision Screening</td>
<td>42 (11.4)</td>
</tr>
<tr>
<td>Failed and seen at optometrist or DHB eye clinic</td>
<td>31 (73.8)</td>
</tr>
<tr>
<td>Failed and not seen at optometrist or DHB eye clinic</td>
<td>11 (26.2)</td>
</tr>
<tr>
<td>Passed and seen at optometrist or DHB eye clinic</td>
<td>15 (4.6)</td>
</tr>
</tbody>
</table>

*Table 5: Number of children in the TDHB eligible for B4SC Vision Screening and the main outcomes of this screening*
11.4% of children failed vision screening in TDHB, compared to 7.7% in SDHB. A two-sided \( \chi^2 \) test between failing vision screening in the SDHB and TDHB had a p-value of less than 0.0213, suggesting that there is a statistically significant difference between the numbers of children failing the vision screening for these two groups.

Of the children who failed the vision screening, 67.9% were not seen by an optometrist or DHB eye clinic in the SDHB, compared to 26.2% in TDHB. A two-sided \( \chi^2 \) test for failing and not being seen versus failing and being seen, comparing the SDHB and TDHB had a p-value of less than 0.00002, suggesting that there is a statistically significant difference between the numbers of children failing the vision screening and not being reviewed by an optometrist or DHB in the study period for these two groups.

### 6.4 Ethnicity

The ethnicity distribution for all children screened was recorded at each B4 School Check visit. The numbers of different ethnicities in children from the SDHB, TDHB, and combined, who were eligible for this study, who failed their B4SC vision screen, and who were found to have a VA of 6/9 or worse in either eye are outlined below (tables 7-9).

<table>
<thead>
<tr>
<th>Ethnicity</th>
<th>Number of all Children Screened by B4SC (%)</th>
<th>Number of Children in Eligible Population (%)</th>
<th>Number of Children out of total who underwent screening who failed (%)</th>
<th>Number of Children found to have reduced VA (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NZ European</td>
<td>1148 (66)</td>
<td>34 (64)</td>
<td>88 (66)</td>
<td>13 (54)</td>
</tr>
<tr>
<td>Ethnicity</td>
<td>Number of all Children Screened by B4SC (%)</td>
<td>Number of Children in Eligible Population (%)</td>
<td>Number of Children out of total who underwent screening who failed (%)</td>
<td>Number of Children found to have reduced VA (%)</td>
</tr>
<tr>
<td>----------------</td>
<td>---------------------------------------------</td>
<td>-----------------------------------------------</td>
<td>-----------------------------------------------------------------------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>NZ Maori</td>
<td>313 (18)</td>
<td>10 (19)</td>
<td>28 (21)</td>
<td>5 (21)</td>
</tr>
<tr>
<td>Asian</td>
<td>107 (6)</td>
<td>4 (7)</td>
<td>10 (7)</td>
<td>2 (8)</td>
</tr>
<tr>
<td>Pacific Islander</td>
<td>73 (4)</td>
<td>2 (6)</td>
<td>6 (4)</td>
<td>2 (8)</td>
</tr>
<tr>
<td>Other</td>
<td>98 (6)</td>
<td>3 (4)</td>
<td>2 (2)</td>
<td>2 (8)</td>
</tr>
</tbody>
</table>

*Table 7: Ethnicity Distributions in SDHB*

<table>
<thead>
<tr>
<th>Ethnicity</th>
<th>Number of all Children Screened by B4SC (%)</th>
<th>Number of Children in Eligible Population (%)</th>
<th>Number of Children out of total who underwent screening who failed (%)</th>
<th>Number of Children found to have reduced VA (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NZ European</td>
<td>109 (30)</td>
<td>13 (30)</td>
<td>9 (22)</td>
<td>4 (18)</td>
</tr>
<tr>
<td>NZ Maori</td>
<td>238 (64)</td>
<td>27 (61)</td>
<td>32 (76)</td>
<td>18 (78)</td>
</tr>
<tr>
<td>Asian</td>
<td>11 (3)</td>
<td>2 (5)</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Pacific Islander</td>
<td>9 (2)</td>
<td>1 (2)</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Other</td>
<td>3 (1)</td>
<td>1 (2)</td>
<td>1 (2)</td>
<td>1 (4)</td>
</tr>
</tbody>
</table>

*Table 8: Ethnicity Distributions in TDHB*

<table>
<thead>
<tr>
<th>Ethnicity</th>
<th>Number of all Children Screened by B4SC (%)</th>
<th>Number of Children in Eligible Population (%)</th>
<th>Number of Children out of total who underwent screening who failed (%)</th>
<th>Number of Children found to have reduced VA (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NZ European</td>
<td>1257 (60)</td>
<td>47 (48)</td>
<td>97 (55)</td>
<td>17 (36)</td>
</tr>
<tr>
<td>Ethnicity</td>
<td>SDHB</td>
<td>TDHB</td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------</td>
<td>------</td>
<td>------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NZ Maori</td>
<td>551</td>
<td>37</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(26)</td>
<td>(38)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asian</td>
<td>118</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(6)</td>
<td>(6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pacific Islander</td>
<td>82</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(4)</td>
<td>(3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>101</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(5)</td>
<td>(4)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 9: Ethnicity Distributions in SDHB and TDHB

6.4.1 Ethnicity Comparison of all Children Included in the Study

The following graphs show the proportion of children within different ethnicities who met the study criteria in both the SDHB and TDHB. (figs. 11,12)
In the SDHB 64% of children who were included in the study were New Zealand European, and 19% were Maori. However, in the TDHB 30% of the children were New Zealand European, and 61% were Maori. A two-sided $\chi^2$ test assessing differences in the frequencies of NZ Maori versus non-Maori children in the study between SDHB and TDHB had a chi-square statistic of 36.75, and a p-value < 0.000001, and so there is a statistically significant difference in the proportion of Maori to non-Maori between the SDHB and TDHB.

6.4.2 Ethnicity Comparison of all Children Screened for Vision and who Failed

The percentages of different ethnicities of all children who failed their B4SC vision screening, in both the SDHB and TDHB, are shown below (figs. 13,14).
A two-sided $\chi^2$ test assessing differences in ethnicity frequencies between all children who were screened for vision in the population and children who had
failed vision screening in SDHB had a p-value of <0.294, which means there is no statistically significant difference between these.

A two-sided $\chi^2$ test assessing differences in ethnicity frequencies between all children who were screened for vision in the population and children who had failed vision screening in TDHB had a p-value of <0.727, which means there is no statistically significant difference between these.

### 6.4.3 Ethnicity Comparison of all Children Included in Study Found to Have Reduced Vision

The percentages of different ethnicities in children who were found to have reduced VA in either eye (6/9 or worse), upon testing at an optometrist or DHB clinic, in both the SDHB and TDHB, are shown below (figs. 15,16).

*Figure 15: Ethnicity Distribution of Children with Reduced Vision (6/9 or worse) in SDHB*
A two-sided $\chi^2$ test assessing differences in ethnicity frequencies between all children who were screening for vision in the population and children who had a VA of 6/9 or worse in either eye in SDHB had a p-value of <0.647, which means there is no statistically significant difference between these.

A two-sided $\chi^2$ test assessing differences in ethnicity frequencies between all children who were screening for vision in the population and children who had a VA of 6/9 or worse in either eye in TDHB had a p-value of <0.360, which means there is also no statistically significant difference between these.

Figure 16: Ethnicity Distribution of Children with Reduced Vision (6/9 or worse) in TDHB

6.5 Socioeconomic Differences Between Southern and Tairawhiti DHBs

The proportions of the populations of SDHB and TDHB in deprivation quintiles, five groups each representing 20% of the population ordered by socioeconomic status, were obtained from census data from the Ministry of Health.(151) The proportions of the total population in each quintile, with quintile 1 being the most
deprived and quintile 5 the least, for both the SDHB and TDHB, are demonstrated in figure 13.

![Figure 17: Percentages of SDHB and TDHB Populations in each SES Quintile](image)

This shows that the SDHB population is underrepresented in higher deprivation levels (quintiles Q1, Q2, Q3) and overrepresented at lower deprivation levels (quintile Q5). There is a Pearson correlation coefficient of 0.853 for the proportion of SDHB population against the deprivation quintile, suggesting that there is a strong positive relationship between SDHB population and the SES quintile. The TDHB population appears underrepresented at the highest SES quintile (Q5), and overrepresented at the lower SES quintiles (Q1 and Q2). There is a Pearson correlation coefficient of -0.866 for the proportion of TDHB population against the deprivation quintile, suggesting that there is a strong negative relationship between SDHB population and the SES quintiles.

Socioeconomic stratification or standardisation for children in this study is not able to be performed as child-specific SES data was not obtained.
6.6 Visual Acuity Comparison

VA data collected from the B4SC Vision Screening was compared to the VA data collected from the first assessment at the optometrist or DHB appointment, for each eye. There were 18 children in the study group where VA was not recorded by the B4SC, or did not undergo VA testing at an optometrist or DHB eye clinic assessment. Frequencies of these VA recordings, for the B4SC and follow-up assessment, are recorded below (fig. 18,19)

![Figure 18: Frequencies of Unilateral VA levels determined by B4 School Check Vision Screening](image-url)
The VA results obtained from the B4SC and the optometrist or DHB were converted to logMAR units, and the means and standard deviations were calculated for each, and compared with a two-sided paired t-test for each eye of the 81 children. It must be noted that the method of VA testing differs among eye health care professionals at DHB and optometry practices, while the B4SC testing protocol dictates Parr letter matching is performed on all children. The testing methods used at DHB and optometry practices, and frequency thereof are listed below (table 10):

<table>
<thead>
<tr>
<th>VA testing methods</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snellen Chart</td>
<td>46</td>
</tr>
<tr>
<td>Lea Symbols</td>
<td>14</td>
</tr>
<tr>
<td>Crowded Kay Pictures</td>
<td>18</td>
</tr>
<tr>
<td>Parr Letter Matching</td>
<td>1</td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
</tr>
</tbody>
</table>

*Table 10: Methods of VA Testing used by Optometrists and DHB Eye Clinics Used*
As the p value from the two-sided paired t-test is less than 0.05, at a confidence of 95% there is some statistical difference between the VA results from the B4SC and VA results from optometrists and DHB eye clinics. Thus, the B4SC data underestimated the child’s ‘gold standard’ VA, which is appropriate for a screening test, to minimise false negatives. There is a correlation between the VA results from the screening and the VA from optometrists/DHB eye clinic. Pearson’s correlation coefficient was 0.655, which suggests that a worse VA in screening predicted a worse true VA in follow-up.

### 6.7 The ‘Error’ of Visual Acuity Screening

It can be assumed that the VA measurements detected by optometrists and DHB eye clinics are the ‘true’ VA. The difference between the ‘true’ VA and the VA from screening is the ‘error’ of each VA measurement. This can be plotted against the ‘true’ VA, to examine the effect that a child’s vision has on the amount of difference between the true VA and screened VA. (fig. 20)
Visually, this shows that at mild to moderate VA deficits, the error of VA from screening is well spread around the mean of the ‘error’, suggesting that screening is as likely overestimate as well as underestimate the VA at these levels. However, at more severe ‘true’ visual acuities, about 0.6 logMAR and worse, most of the error tends to be positive, suggesting that screening children with very low vision is likely to underestimate the degree of VA deficit. The Pearson correlation coefficient for this comparison is 0.514, suggesting that there is a correlation between having a worse VA, and having an increased amount of ‘error’ in VA screening in one direction.

6.8 Ocular Abnormalities in the Study Population

Any cause of reduced VA, defined as a VA of 6/9 or worse in either eye, or other eye pathology, as determined by optometrist and DHB eye clinic assessment were recorded. The numbers for each cause of reduced VA, or vision abnormality identified by an optometrist or DHB eye clinic for SHDB, TDHB, and collectively, are shown below (tables 12-14).
<table>
<thead>
<tr>
<th>Number of Screened Children Seen by an Optometrist or DHB eye clinic in SDHB</th>
<th>53</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of confirmed reduced VA</td>
<td>24</td>
</tr>
<tr>
<td><strong>Amblyopia</strong></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>4</td>
</tr>
<tr>
<td>Anisometropic</td>
<td>4</td>
</tr>
<tr>
<td>Strabismic</td>
<td>0</td>
</tr>
<tr>
<td>Deprivational</td>
<td>0</td>
</tr>
<tr>
<td><strong>Refractive Error</strong></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>24</td>
</tr>
<tr>
<td>Hypermetropia (+2.50D or worse)</td>
<td>7</td>
</tr>
<tr>
<td>Astigmatism (1.50 D or worse)</td>
<td>11</td>
</tr>
<tr>
<td>Myopia (-1.50 D or worse)</td>
<td>2</td>
</tr>
<tr>
<td>Anisometropia (Difference of 1.0 D for hypermetropic, 2.0 D for myopic, and 1.50 D for cylindrical)</td>
<td>4</td>
</tr>
<tr>
<td><strong>Strabimus</strong></td>
<td>2 (2 exotropia)</td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td>0</td>
</tr>
</tbody>
</table>

*Table 12: Causes of Reduced VA and other Ocular Pathology in SDHB*
<table>
<thead>
<tr>
<th>Cause</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Screened Children Seen by Optometrist or DHB eye clinic in TDHB</td>
<td>46</td>
</tr>
<tr>
<td>Number of confirmed reduced VA</td>
<td>23</td>
</tr>
<tr>
<td>Amblyopia</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3</td>
</tr>
<tr>
<td>Anisometropic</td>
<td>2</td>
</tr>
<tr>
<td>Strabismic</td>
<td>1</td>
</tr>
<tr>
<td>Deprivational</td>
<td>0</td>
</tr>
<tr>
<td>Refractive Error</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>22</td>
</tr>
<tr>
<td>Hypermetropia (+2.50D or worse)</td>
<td>5</td>
</tr>
<tr>
<td>Astigmatism (1.50D or worse)</td>
<td>12</td>
</tr>
<tr>
<td>Myopia (-1.50 D or worse)</td>
<td>2</td>
</tr>
<tr>
<td>Anisometropia (Difference of 1.0D for hypermetropic, 2.0 D for myopic, and 1.50 D for cylindrical)</td>
<td>3</td>
</tr>
<tr>
<td>Strabismus</td>
<td>1 (1 exotropia)</td>
</tr>
<tr>
<td>Other</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 13: Causes of Reduced VA and other Ocular Pathology in TDHB
<table>
<thead>
<tr>
<th>Number of Screened Children Seen by an Optometrist or DHB eye clinic in SDHB</th>
<th>99</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of confirmed reduced VA</td>
<td>47</td>
</tr>
<tr>
<td>Amblyopia</td>
<td>Total</td>
</tr>
<tr>
<td></td>
<td>Anisometropic</td>
</tr>
<tr>
<td></td>
<td>Strabismic</td>
</tr>
<tr>
<td></td>
<td>Deprivalional</td>
</tr>
<tr>
<td>Refractive Error</td>
<td>Total</td>
</tr>
<tr>
<td></td>
<td>Hypermetropia (+2.50D or worse)</td>
</tr>
<tr>
<td></td>
<td>Astigmatism (1.50 D or worse)</td>
</tr>
<tr>
<td></td>
<td>Myopia (-1.50 D or worse)</td>
</tr>
<tr>
<td></td>
<td>Anisometropia (Difference of 1.0 D for hypermetropic, 2.0 D for myopic, and 1.50 D for cylindrical)</td>
</tr>
<tr>
<td>Strabimus</td>
<td>3 (3 exotropia)</td>
</tr>
<tr>
<td>Other</td>
<td>0</td>
</tr>
</tbody>
</table>

*Table 14: Causes of Reduced VA and other Ocular Pathology in SDHB and TDHB*
### 6.9 Cycloplegic Refraction of Children in Study Population

The mean and 95% confidence intervals for the spherical equivalent of cycloplegic refraction data in for children with normal vision, hypermetropia, and myopia, and anisometropia (in differences between each eye) for the SDHB, TDHB, and combined, as well as mean and 95% confidence interval of the cylindrical power for astigmatism for each DHB, are shown below (tables 15, 16).

<table>
<thead>
<tr>
<th>Type of Refractive Error (n)</th>
<th>Mean Cycloplegic Refraction (D)</th>
<th>95% Confidence Interval (D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal (29)</td>
<td>+0.55</td>
<td>+0.39, +0.70</td>
</tr>
<tr>
<td>Hypermetropia (7)</td>
<td>+4.00</td>
<td>+3.30, +4.70</td>
</tr>
<tr>
<td>Astigmatism (11)</td>
<td>1.72</td>
<td>0.73, 2.71</td>
</tr>
<tr>
<td>Myopia (2)</td>
<td>-1.88</td>
<td>-2.02, -1.74</td>
</tr>
<tr>
<td>Anisometropia (4)</td>
<td>+3.54</td>
<td>+1.95, +5.53</td>
</tr>
</tbody>
</table>

*Table 15: Mean and 95% Confidence Intervals for Cycloplegic Refraction in SDHB*

<table>
<thead>
<tr>
<th>Type of Refractive Error (n)</th>
<th>Mean Cycloplegic Refraction (D)</th>
<th>95% Confidence Interval (D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal (24)</td>
<td>+0.49</td>
<td>+0.35, +0.63</td>
</tr>
<tr>
<td>Hypermetropia (5)</td>
<td>+3.24</td>
<td>+2.66, +3.82</td>
</tr>
<tr>
<td>Astigmatism (12)</td>
<td>1.45</td>
<td>1.19, 1.71</td>
</tr>
<tr>
<td>Myopia (2)</td>
<td>-2.13</td>
<td>-2.54, -1.71</td>
</tr>
<tr>
<td>Anisometropia (3)</td>
<td>+2.88</td>
<td>+0.88, +6.02</td>
</tr>
</tbody>
</table>

*Table 16: Mean and 95% Confidence Intervals for Cycloplegic Refraction in TDHB*
### 6.10 Management of Children in Study Population

Possible management for children seen by an optometrist included discharge/review later, glasses, occlusion therapy, or ophthalmology referral, and possible management for children seen at a DHB eye clinic included discharge, glasses, occlusion therapy, or surgery. The number of children receiving various treatments from optometrists and DHB eye clinics are shown below (tables 17-20).

<table>
<thead>
<tr>
<th>Number of Cases</th>
<th>Type of Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seen by Optometrist: 22</td>
<td></td>
</tr>
<tr>
<td>No ocular issue or pathology: 15</td>
<td>Review Later: 15</td>
</tr>
<tr>
<td>Refractive Error: 6</td>
<td>Glasses: 5 \n Review Later: 1</td>
</tr>
<tr>
<td>Amblyopia: 1</td>
<td>Glasses: 1 \n Patching: 0</td>
</tr>
<tr>
<td>Strabismus: 1</td>
<td>Refer to DHB Ophthalmology: 1</td>
</tr>
</tbody>
</table>

*Table 17: Management of Children Seen by an Optometrist in the SDHB*

<table>
<thead>
<tr>
<th>Number of Cases</th>
<th>Type of Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seen by DHB Eye Clinic: 31</td>
<td></td>
</tr>
<tr>
<td>No ocular issue or pathology: 12</td>
<td>Discharge: 12</td>
</tr>
<tr>
<td>Refractive Error: 18</td>
<td>Glasses: 15 \n Review Later: 3</td>
</tr>
<tr>
<td>Amblyopia: 3</td>
<td>Glasses: 3 \n Patching: 2</td>
</tr>
<tr>
<td>Strabismus: 1</td>
<td>Active Review: 1</td>
</tr>
</tbody>
</table>

*Table 18: Management of Children Seen at a SDHB Eye Clinic*
<table>
<thead>
<tr>
<th>Number of Cases</th>
<th>Type of Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seen by Optometrist: 46</td>
<td></td>
</tr>
<tr>
<td>No ocular issue or pathology: 22</td>
<td>Review Later: 22</td>
</tr>
<tr>
<td>Refractive Error: 23</td>
<td>Glasses: 21</td>
</tr>
<tr>
<td></td>
<td>Review Later: 2</td>
</tr>
<tr>
<td>Amblyopia: 3</td>
<td>Glasses: 2</td>
</tr>
<tr>
<td></td>
<td>Patching: 1</td>
</tr>
<tr>
<td></td>
<td>Refer to Ophthalmology: 1</td>
</tr>
<tr>
<td>Strabismus: 1</td>
<td>Refer to DHB Ophthalmology: 1</td>
</tr>
</tbody>
</table>

Table 19: Management of Children Seen by an Optometrist in the TDHB

<table>
<thead>
<tr>
<th>Number of Cases</th>
<th>Type of Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seen by DHB Eye Clinic or Optometrist: 46</td>
<td></td>
</tr>
<tr>
<td>No ocular issue or pathology: 22</td>
<td>Review Later: 22</td>
</tr>
<tr>
<td>Refractive Error: 23</td>
<td>Glasses: 21</td>
</tr>
<tr>
<td></td>
<td>Review Later: 2</td>
</tr>
<tr>
<td>Amblyopia: 3</td>
<td>Glasses: 2</td>
</tr>
<tr>
<td></td>
<td>Patching: 1</td>
</tr>
<tr>
<td></td>
<td>Refer to Ophthalmology: 1</td>
</tr>
<tr>
<td>Strabismus: 1</td>
<td>Refer to DHB Ophthalmology: 1</td>
</tr>
</tbody>
</table>

Table 20: Management of All children seen by an optometrist or DHB eye clinic in SDHB or TDHB
6.11 False Positive, False Negative, True Positive, and True Negative Outcomes

99 children who were screened for vision within the study period were seen at an optometrist or DHB Eye clinic. Of these, 74 had failed the vision screening, and 25 had passed. Tables 21-23 show the numbers of true positive (where ‘gold standard’ VA testing at screening would have resulted in failure), false positive (where ‘gold standard’ VA testing at screening would have resulted in passing), true negative (where ‘gold standard’ VA testing at screening would have resulted in passing), and false negative (where ‘gold standard’ VA testing at screening would have resulted in failure) referrals from the B4SC Vision Screening for children seen at an optometrist or DHB eye clinic, as determined by the post-screening follow-up appointment, for the SDHB, TDHB, and combined, respectively.

<table>
<thead>
<tr>
<th>Screening Result</th>
<th>Follow-up Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Failed: 43</td>
<td>True Positive: 23</td>
</tr>
<tr>
<td></td>
<td>False Positive: 20</td>
</tr>
<tr>
<td>Passed: 10</td>
<td>True Negative: 9</td>
</tr>
<tr>
<td></td>
<td>False Negative: 1</td>
</tr>
</tbody>
</table>

*Table 21: Screening outcomes and follow-up results for the SDHB*

<table>
<thead>
<tr>
<th>Screening Result</th>
<th>Follow-up Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Failed: 31</td>
<td>True Positive: 19</td>
</tr>
<tr>
<td></td>
<td>False Positive: 12</td>
</tr>
<tr>
<td>Passed: 15</td>
<td>True Negative: 11</td>
</tr>
<tr>
<td></td>
<td>False Negative: 4</td>
</tr>
</tbody>
</table>

*Table 22: Screening outcomes and follow-up results for the TDHB*
Table 23: Screening outcomes and follow-up results for the SDHB and TDHB

<table>
<thead>
<tr>
<th>Screening Result</th>
<th>Follow-up Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Failed: 74</td>
<td>True Positive: 42</td>
</tr>
<tr>
<td></td>
<td>False Positive: 32</td>
</tr>
<tr>
<td>Passed: 25</td>
<td>True Negative: 20</td>
</tr>
<tr>
<td></td>
<td>False Negative: 5</td>
</tr>
</tbody>
</table>

6.12 Positive Predictive Value

The positive predictive value is equal to the proportion of those cases which fail the screening who do have a true VA of 6/9 or worse in either eye. Calculation of this assumes there was no factor other than failing the B4SC vision screening programme influencing the likelihood of presentation at an optometrist or DHB eye clinic within the study period.

The PPV of the B4SC vision screening programme in SDHB = 53.5%

The PPV of the B4SC vision screening programme in TDHB = 61.3%

The PPV of the B4SC vision screening programme in both the SDHB and TDHB = 56.8%

NPV cannot be calculated as the study design did not allow for representative data to be obtained from those children who passed vision screening.
6.13 Estimation of Sensitivity, Specificity, and Negative Predictive Value

This study was a retrospective audit, and only looked at the data for children who had been screened as well as being seen by an optometrist or DHB eye clinic within the study period. Therefore, no data other than what was collected at the time of vision screening was gathered for children who were not seen at an optometrist of DHB eye clinic, regardless of their vision screening outcome. This unfortunately means that determination of the true sensitivity, specificity, and NPV is not possible. However, it is possible to calculate a range of possible values for these, by estimating the vision status of the children who were screened, regardless of screening outcome, who were not seen by an optometrist of DHB eye clinic within the study period.

One can estimate the prevalence of conditions that would cause a VA loss in children at four years, which would be significant enough to not pass the B4SC vision screening, by using data from analogous studies and populations. The main diseases affecting the vision status of a four-year-old are amblyopia and/or refractive error. One can calculate a window of possible outcomes for the measures of screening accuracy by using two assumptions: the best case, which assumes the unseen children would have the maximum number of allowed true positives and true negatives, and the worst-case, which assumes the unseen children would have the maximum allowed number of false positives and false negatives.

The prevalence of amblyopia/and or refractive error that causes a reduction in VA to at least 6/9 in either eye in NZ has been found to be 5.45%(98), and so the number of expected number of cases of reduced VA in this study population is approximately 119 children. As there were 47 cases of confirmed reduction in VA, it can be assumed there around about 72 cases of reduced VA in the population who received screening, but did not present to an optometrist or DHB eye clinic during the study period.
Table 24 shows the best case for the vision screening: that after accounting for known total expected number of positives (119) and the total number of positive screening results (176), the maximum number of positive cases were screened as positive, and the maximum number of negative cases were screened as negative.

<table>
<thead>
<tr>
<th>True Result</th>
<th>Screening Outcome</th>
<th>Positive</th>
<th>Negative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive</td>
<td>TP: 114</td>
<td>FN: 5</td>
<td>119</td>
</tr>
<tr>
<td>Negative</td>
<td>FP: 62</td>
<td>TN: 2008</td>
<td>2070</td>
</tr>
<tr>
<td></td>
<td>176</td>
<td>2013</td>
<td>2189</td>
</tr>
</tbody>
</table>

Table 24: Best-case scenario for B4SC Vision Screening outcomes in SDHB and TDHB

Best-case Sensitivity = 95.8%

Best-case Specificity = 97.0%

Best-case NPV = 99.9%

Table 25 shows the worst case for the vision screening: that after accounting for known total expected number of positives (119) and the total number of positive screening results (176), the maximum number of positive cases were screened as negative, and the maximum number of negative cases were screened as positive.
<table>
<thead>
<tr>
<th>True Result</th>
<th>Screening Outcome</th>
<th>Positive</th>
<th>Negative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive</td>
<td>TP: 42</td>
<td>FN: 77</td>
<td>119</td>
</tr>
<tr>
<td>Negative</td>
<td>FP: 134</td>
<td>TN: 1936</td>
<td>2070</td>
</tr>
</tbody>
</table>

176 2013 2189

*Table 25: Worst-case scenario for B4SC Vision Screening outcomes in SDHB and TDHB*

Worst-case Sensitivity = 35.3%

Worst-case Specificity = 93.5%

Worst-case NPV = 96.1%
Chapter Seven - Discussion

7.1 Main Findings

7.1.1 How Well the B4SC Vision Screening Programme is working

The primary aim of this study was to evaluate how well the B4 School Check vision screening programme in New Zealand is performing its function, by examining the vision screening results, and comparing these to data from optometrist and DHB eye clinic assessments for children who have been screened for vision, in two geographically, ethnically, and economically distinct District Health Boards. If there is to be a public investment into a population vision screening programme, it should be able to detect as many children with a vision problem as possible, meaning it should reach the highest number of eligible children it can, and have the most accurate screening results: not passing excess children who do have visual deficits nor failing children with normal vision.

7.1.2 Coverage

Screening programmes should be able to reach the majority of the target population, to maximise the number of cases that are detected so there are no cases left untreated. In the SDHB, the number of children identified as eligible for screening between 1 April and 30 September 2016 was 1888, 1739 (92.1%) of whom received screening, excluding those children identified as already under eye health care. In the TDHB, the number of children identified as eligible for screening within the study period was 376, 370 (98.4%) of whom received screening, excluding those children identified as already under eye health care. Overall, there were 2109 children screened for vision by the B4SC within the study period, 93.1% of the total 2264 eligible. These are high percentages of children in the population who do receive screening, which is indicative that the B4 School Check
is effective at providing vision screening to a large proportion of eligible children. However, this is not as high as has been reported in other health systems, for example, in Sweden, where vision screening in 4 year olds has an uptake of over 99% of the population, suggesting there is still capacity for improvement in the reach of the B4SC. (169) Possible reasons for coverage of the B4SC not reaching 100% of the population may be due to parents declining childhood vision screening, which may indicate a lack of knowledge regarding the importance of vision screening, or perhaps there is some difficulty in VHTs arranging vision screening, and either there being not enough VHTs to meet the screening need, or regional challenges that occur with sizable populations in New Zealand living rurally and are difficult for VHTs to meet, for example. However, New Zealand vision screening coverage does do well compared to some populations: uptake of vision screening has been found to be as low as 51% nationally in Iran (170), and 45% in Alberta, Canada. (171)

One issue with implementation of vision screening programmes is the timing of screening. There must be a balance where screening occurs early enough in a child’s visual development so that prevention and treatment of amblyopia and its risk factors is possible and optimised, and not too early that children who do eventually develop amblyopia are missed. The B4SC aims to screen children’s vision shortly after their fourth birthday. However, this can mean by this time a significant proportion of children with visual and ocular defects may have already presented to eye health care providers, making vision screening of these children redundant. The numbers of children identified for vision screening and already under care of an eye health care provider between 1 April and 30 September 2016 in the SDHB was 54 (2.8%), and in the TDHB 26 (6.5%). This is not an insignificant number, especially when compared to the numbers of children who are failing vision screening (134 and 42 in SDHB and TDHB, respectively). This suggests that screening may be occurring too late, as children are already presenting to eye health care providers regardless of screening. However, it was not investigated what the reason for these presentations were, nor how the children came to
present, i.e. through parental concern or issues detected in other child health checks.

One way to analyse whether children with vision problems are being detected too late is to examine long-term vision screening outcomes. Currently, no data exists for the long-term outcomes of the B4SC vision screening, and whether it prevents amblyopia. However, a long term study in Sweden of vision screening of four-year-olds found that the prevalence of amblyopia decreased from 2% to 0.2% from 1970 to 1992, which demonstrate that screening does reduce prevalence. (162)

7.1.3 Accuracy of Vision Screening

As well as screening the maximum number of children it can, a vision screening programme also ought to be as accurate as possible. The B4SC vision screening programme uses a VA level of 6/9 in one eye, or 6/12 in either or both eyes for the threshold for referral, i.e. a screening fail. Almost all first vision assessments at an optometrist or DHB eye clinic for children includes measuring the uncorrected visual acuity of each eye, and because these measurements are likely to guide further treatment and be more indicative of a child’s true VA, these VA measurements were taken as the true levels or “gold standard’. Thus, for each child referred from the B4SC and seen by an optometrist or DHB eye clinic in the study period, VA data was available from the screening programme, and the clinical assessment.

Our study found relatively small numbers of children who had failed vision screening and had been assessed at an optometrist or DHB eye clinic (43 and 31 for SDHB and TDHB respectively). Of these, approximately half were found to have a truly reduced VA (23 and 19 for SDHB and TDHB respectively). Of those children who passed vision screening but had still been assessed at an optometrist or DHB eye clinic during our study period (10 and 15 for SDHB and TDHB respectively),
only a small minority were found to have abnormal VA (1 and 4 for SDHB and TDHB respectively).

7.1.4 Positive Predictive Value

The positive predictive value, which is the proportion of cases who fail the screening who do have true VA that would lead to a fail of a vision screen, of the B4SC vision screening programme in SDHB was 53.5%, in TDHB 61.3%, and collectively 56.8%. This means that only slightly over half the cases of children screened for vision and who fail, do truly have a visual deficit. The implication for this is that a significant number of children are being referred for further assessment, when they have no visual problems, which can lead to worry for parents and the child, economic cost to the parents for initial assessment at an optometrist, and unnecessary economic costs and increased demand of limited resources on DHBs that assess children referred from the B4SC. A study of the B4SC vision screening programme in Counties-Manukau DHB (CMDHB) found a PPV of 31%, due to a high number of false positives. (168) This was partially explained by the large proportion of children in the CMDHB who did not speak English at home, and so were referred on for more detailed visual assessment. Thus, DHBs where more children would speak English at home (such as SDHB and TDHB) would expect fewer false positives, and thus a higher PPV. Other screening programmes have reported comparable PPVs ranging from 35 to 81%, including the Rotterdam AMblyopia Screening Effectiveness Study (RAMSES), a seven year follow up study, which found a PPV of 42%. (172–175)

There are numerous potential causes for such a low PPV in the B4SC childhood vision screening. Positive predictive value directly correlates with prevalence. Amblyopia is a relatively uncommon condition (prevalence of 1-5%) and so most children screened will not have any visual deficit, meaning there is a greater pool of visually normal children from which to draw false positives (95-99% of children screened), compared to the pool from which to draw true positives. This means
that even with relatively high sensitivity and specificity, there can still be a low PPV. Children who are screened at four years of age may be uncooperative with vision screening, and this may lead to the VHTs wanting to refer these children on, without properly measuring the child’s VA. Also, VHTs may prefer to err on the side of caution with vision screening and refer children with borderline vision lest they have a vision problem that is missed. Another reason for the low PPV may be that visual acuity testing itself may be subject to wide degree of variation between testers, who are not as highly trained at measuring VA as optometrists or other eye health care providers, and variation between testing conditions, such as screening occurring in schools, which may have inadequate lighting, other distractions, and not measuring VA from the exact distance (4m) for instance. VHTs may also not be as thorough with testing compared to optometrists and orthoptists, as they are functioning as screeners rather than diagnosticians.

### 7.1.5 Negative Predictive Value, Sensitivity, and Specificity

NPV, sensitivity, and specificity of the B4SC vision screening could not be directly calculated because the study design did not allow representative data for children who passed the vision screening to be collected, meaning that the children who were presenting to optometrists or DHB eye clinics having passed the screening, were unlikely to have been a representative sample of all children who passed the screening. Therefore, these values had to be estimated by determining the expected number of cases of reduced VA in the population of four year olds screened, with analogous prevalence data, and finding a possible range of values using the best-case (the unaccounted numbers of false screening results were minimised, and the unaccounted numbers of true screening results were maximised), and worst-case (the unaccounted numbers of false screening results were maximised, and the unaccounted numbers of true screening results were minimised) screening outcomes.
The range of possible NPVs were 96.1% - 99.9%. This means that the true probability of a child who passes vision screening of not having a reduction in vision is between 96.1 and 99.9%. These are high values and suggest that very few children who pass the screening will have a visual problem, meaning there is likely to be very few children in the community with unidentified and untreated visual deficits. Potential reasons for the high NPV are that children who are near the threshold for screening referral are referred anyway, corroborated by the relatively low PPV, and so all the children who are passing vision screening are passing clearly. Another reason is that in relatively rare conditions, such as amblyopia, most instances of passing screening will happen to be true negatives, simply because most cases will be negatives.

The range of sensitivity values was 35.3% - 95.8%. The sensitivity is the proportion of instances of reduced vision (6/9) that would be detected with screening. The range of possible sensitivity values is very large, and therefore it is difficult to draw any meaningful conclusions from this. However, there have been numerous studies examining the sensitivity of various screening programmes, and has found sensitivity values to range from 65 to 85%. (176–178)

The range of specificity was 93.5% - 97.0%. The specificity is the proportion of instances of normal vision that pass vision screening. This is a relatively narrow interval, and relatively high, suggesting that most cases of normal vision are not being referred by the B4SC.

7.1.6 Visual acuity screening accuracy

Another way to assess the accuracy of the B4SC vision screening is to look at the VA results for each eye of each child, from both the B4SC and that child’s follow up assessment at either an optometrist or DHB eye clinic. Two-sided paired t-test analysis between VA data from the B4SC and from optometrist and DHB eye clinic assessments gave a p value of less than 0.045, which means there is a
statistically significant difference between these two sets of data, at 95% confidence.

This difference was further explored by analysing the ‘error’ of the B4SC screening data. It was assumed that the VA data obtained from optometrists and DHB eye clinics was the child’s true VA, and the difference between these values and the B4SC VA data values was the ‘error’ of the screening. At lower VA deficits, vision better than 6/12, the ‘error’ seems to be evenly distributed as overestimating and underestimating the true VA. However, at worse true VA deficits, most of the ‘error’ of the vision screening is due to the B4SC underestimating the degree of VA deficit. This is probably due to the nature of a screening programme, where it does not aim to quantify the precise level of VA deficit, rather identify cases that meet the threshold for referral, so they can be further investigated by eye health care providers. This means that children with severe levels of true VA reduction may not have their extent of VA reduction assessed by VHTs, because the child fails the screening, and is referred without further testing. This is good because it means extra effort is not used to try to precisely quantify the visual deficit of every child during screening, which is an efficient use of VHT time.

Other reasons for the discrepancy between the VHTs’ VA results and the ‘gold standard’ VA results are legion, and include major differences in VA testing method between VHTs and eye health care providers, true changes to a child’s vision between being screened and appointment with an eye health care professional, and screening conditions not always being ideal. If the location where the vision screening is occurring is not adequate for testing vision, this may alter the VA results, for example, if there was insufficient lighting in the room the screening was occurring, this may underestimate the child’s VA. Also, if the screening is occurring at a busy preschool or disruptive household, the child’s attention may wane, and the VHT may interpret this as the child not being able to see.
7.2 Other outcomes from this study

This study also aimed to describe the causes and nature of amblyopia and refractive error, differences in vision screening and amblyopia prevalence between SDHB and TDHB, differences in vision screening between different ethnicities, attendance at various eye health care providers, and management or amblyopia and refractive error.

7.2.1 Amblyopia and Refractive Error Outcomes

Of those children identified by our study as having reduced VA (below 6/9) on testing at the optometrist or DHB eye clinic (24 and 23 for SDHB and TDHB respectively), almost all were cases of refractive error (24 and 22 for SDHB and TDHB respectively) – mostly astigmatism (11 and 12 for SDHB and TDHB respectively). There were only four cases of amblyopia identified in SDHB patients, with three identified in TDHB. Interestingly only three cases of strabismus were identified, two in SDHB and one in TDHB, all of which were cases of exotropia.

The rates of different refractive errors in TDBH and SDHB were recorded. 50% of refractive errors were astigmatism, 26% were hypermetropia, 9% were myopia, and 15% were anisometropia. These proportions of causes of refractive error are not too different from the ones found in CMDHB, which found 46% of cases were astigmatism, 36% hypermetropia, 3% myopia, and 16% anisometropia. (168)

While strabismus in a four-year-old age group is more likely to be esotropia, every case identified in this study was exotropia. (83) This suggests that most cases of esotropia are not identified in vision screening, or that these children are already known to eye health care providers, possibly because of esotropia being apparent sooner, and are included in the number of children who were already under care at the time of screening. It has been found that the age of onset of
accommodative esotropia is three months to seven years, but with a mean age of diagnosis of 2.5 years. (179)

7.2.2 Management of Amblyopia and Refractive Error

The management of children who were both screened and presented to an optometrist or DHB eye clinic was recorded. All children who were identified as not having a reduced VA or any eye pathology were not treated, and either discharged or often discharged with a plan to be reviewed again at a later date (which occurred at most optometry practices). All children identified as having refractive error (as per the level used for the definitions in this study) were prescribed glasses.

Of the 7 children who were diagnosed with amblyopia, three received glasses only and three received both glasses and patching. One patient with strabismic amblyopia was referred to an ophthalmologist. There are no set clinical guidelines for the management of amblyopia in New Zealand, and treatment often depends on clinician preferences. However, most cases of anisometropic amblyopia can be effectively treated with glasses alone.

Of the 30 children presenting to optometrists who were found to have a visual problem, only 1 was referred to an ophthalmologist for follow up assessment, which was for exotropic strabismus and amblyopia. This suggests that the majority of paediatric patients at optometry clinics are not referred, and most cases of refractive error and amblyopia are treated by optometrists. One case of strabismus was managed by an optometrist without immediate referral to an ophthalmologist.
7.2.3 Southern DHB versus Tairawhiti DHB

There are significant differences between the Southern and Tairawhiti DHBs, particularly regarding size, population number, ethnicity distribution, and socioeconomic status, and thus a study investigating the B4SC in two significantly different DHBs allowed a measure of how well vision screening was working in two different populations. This means that any differences in screening and vision outcomes between SDHB and TDHB may be possibly partially due to these differences in the ethnic make-up of each DHB, SES differences between the DHBs, and differences in the sizes and geography of the DHBs.

There are statistically significant differences in the ethnic proportions between SDHB and TDHB. In the SDHB 66% of children screened by the B4SC were NZ European, and 18% NZ Maori, compared to TDHB, where 30% of the children screened were NZ European, and 64% NZ Maori. There are also significant socioeconomic differences between these two regions, with SDHB being underrepresented for deprivation, and TDHB overrepresented for deprivation. SDHB also has a far larger catchment area, in terms of geography and population.

There was a statistically significant difference in the failure rate of screening between the SDHB and TDHB, of 7.7% compared to 11.4%. This may be attributable to true differences in the vision states between these populations, or differences in the screening itself. However, of the children being seen by optometrists and DHB eye clinics, 55% did truly have a vision problem in SDHB, compared to 50% in TDHB. This difference in vision between children from each region was not statistically significant, suggesting that the children in TDHB may be more likely to fail vision screening, regardless of their true vision status, which could suggest may be a systematic difference in the process of screening between the two regions, despite identical guidelines.

There was also a statistically significant difference between the quantity of data collected between the SHBD and TDHB, with 67.9% of children who failed vision screening in SDHB not being identified at either optometrist or DHB eye clinic,
compared to 26.2% in TDHB who did not present. This difference may be due to several reasons. There are no children in TDHB who are referred directly to the DHB eye clinic in Gisborne Hospital, and all referrals must be through a community optometrist. Data was collected from all three optometry practices in TDHB, which means there is a high probability that all children who would present in the study period were identified. However, as over one quarter of children who failed were not seen by an optometrist, this suggests there is a large proportion of children who fail vision screening who do not present at all. One practice in TDHB assessed almost all the children seen by optometrists and the B4SC, and this practice did offer free assessment for children.

In the SHDB, there was a high number of children failing vision screening were not identified at an optometrist or DHB eye clinic, and possible reasons for this include missing data from four optometry practices: three practices did not supply any data for children they had seen within the study period, and a busy practice in the SDHB was not able to supply data that was collected over three months of the study period, due to unavoidable software issues. Also, as much of the data collection from optometrists depended on the optometrists identifying children in the relevant age group as they were seen continuously for seven months, and practice software often excluded retroactive searching of patients who were seen at specific dates, it is possible that many optometry practices missed some children who would have been eligible for the study, simply due to forgetting to record identifying parameters for children seen, and multiple optometrists working at single practices making it difficult to have 100% of children seen identified within each practice.

In the SDHB, vision assessment at the Dunedin Hospital is free, and so this may be where VHTs may suggest to parents of children who fail vision screening to go. However, unlike at an optometry practice, there is a significant waiting time to be assessed at the DHB eye clinic (which is limited to four months as per Ministry of Health guidelines). Therefore, if many parents prefer their child to be seen at a DHB eye clinic, where children may not receive an appointment until four months later (perhaps even later if there is delay for the parent to arrange the
appointment) the delay in receiving their appointment may have led to some children's clinical assessments not being identified by our study. The data collection for DHB eye clinic data extended until the 30 November (two months after the B4SC vision screening study period) to attempt to account for these differences but may not have been sufficient to catch all children presenting from B4SC referral – a four-month extension of the DHB data collection window was not possible owing to time limitation of the author’s programme of study.

It is nonetheless concerning that 68% of children failing B4SC vision screening in the SDHB between April and September 2016, had not been seen by optometrist or DHB eye clinic by the end of October 2016 and November 2016, respectively.

### 7.2.4 Ethnicity and Vision Screening

Currently, there is little New Zealand data on differences in amblyopia prevalences between various ethnic groups. One study published in 1970 did describe the differences in refractive error prevalence between groups, and found that NZ Europeans are more likely to have both myopic and hypermetropic refractive error than Pacific people. (180) Ethnicity may potentially affect vision screening outcomes for children, either via systematic differences between various ethnicities in the process of screening, such as language and cultural differences affecting the screening outcome, and differences in vision status attributable to ethnicity. Ethnicity is routinely recorded by VHTs in the B4SC. The ethnicities used in this study included NZ European, NZ Maori, Pacific Islander, Asian, and Other (a broad category encompassing children from South American, Middle Eastern, and African descent).

However, there was no statistical difference found between the number of children from each different ethnicity receiving screening and failing screening or receiving screening and having a reduced VA in either the SDHB or TDHB. This suggests that there is little to no difference in the provision of screening and rates of vision abnormalities. However, the CMDHB B4SC study did find that NZ Maori
and Pacific Islanders were more likely to decline vision screening, compared to NZ Europeans, suggesting an avenue for vision disparities between these groups. (168)

Overall, it was found that NZ Maori were over-represented among those with a reduced VA (78% of reduced VAs), while only comprising 64% of the children screened by the B4SC. However, in the context of no statistically significant difference in the proportion of NZ Maori who have a reduced VA compared to the total screened when comparing TDHB and SDHB separately, this disproportional effect is likely an artefact from the fact that relatively more data was collected from TDHB. This meant that while NZ European was the largest group screened overall, NZ Maori made up a larger proportion of those children eligible for the study, and thus found to have a VA reduction.

7.2.5 Optometrist versus DHB Management

One of the principles of Screening of Wilson and Junger, is that there must be facilities for diagnosis and treatment following screening. Children referred from the B4SC have the option of either being seen by a community optometrists, a DHB eye clinic, or a private ophthalmologist. In the TDHB, the DHB eye clinic does not take referrals directly from the B4SC, and so children are firstly referred to an optometrist.

In TDHB, one optometry practice accounted for the clear majority of children who were eligible for the study, and this practice also offers free first assessment for children. The reason so many of the children presented here may be due to the parents of these children being encouraged by VHTs, who would be aware that this practice is the only source of free eye assessment, or parents seeking out the free option.

There may be a systematic difference in children who present to optometrists versus children presenting to the DHB eye clinic at Dunedin Hospital. The DHB eye clinic does not cost the parents, whereas most optometry assessments do. This
may mean that children from higher SES families may be seen by optometrists more than children from low SES families. Therefore, SES analysis of each child receiving vision screening and its follow-up may be an area of future interest. Assessment at Dunedin Hospital eye clinic is easily accessible to only children who live in Dunedin, usually, meaning children who live in rural regions in the SDHB only really have access to local optometrists, which is not free. This economic cost may be a deterrent for some children to have a vision assessment. However, the Dunedin Hospital eye clinic has a longer waiting time to be seen than an optometrist, and so parents who opt to be seen at Dunedin Hospital, may mean there is slight delay in the children receiving treatment.

There was only one case of an optometrist referring a child for ophthalmological assessment, which was for exotropic strabismus. All cases of refractive error and anisometropic amblyopia identified in this study by optometrists were managed by the optometrists, and treatment of these conditions falls within the scope of practice of optometrists. This suggests that optometrists are managing most cases referred to them from the B4SC themselves.

7.3 Methodological Considerations

The design of this study was a retrospective audit, collecting data on all children seen at community optometrists and DHB eye clinics in the SDHB and TDHB, and comparing them to data collected from the B4SC at the time of screening. This method was chosen because it allowed comparison between the VA data from the B4SC and follow-up assessment.

However, there are several issues with this design. Foremost, this study did not allow calculation of the true sensitivity, specificity, and negative predictive value. This information would need to have been collected with a different study design, in which a random group of children screened by the B4SC were tested for vision, regardless of their presentation to an optometrist or DHB eye clinic.
Data collected from community optometrists was voluntary, and depended on the optometrists collecting and supplying data for every child between 4 and 7 years, continually for seven months. This presented some issues, such as three practices in the SDHB not supplying any data (out of 21), and one only being able to supply data for half of the data collection period. Also, there is a strong possibility of practices not supplying the data of every child aged 4 to 7 years who presented to the practice, evidenced by the 67.8% and 26.2% of children who failed screening, who were not seen by an optometrist or DHB eye clinic in the SDHB and TDHB, respectively.

The ideal way to measure how well the B4SC is performing would be with a randomised control trial comparing long-term vision outcomes of children who do receive preschool vision screening to those who do not. However, this is not practical to perform, as the it would require follow up for years, and does not have clinical equipoise, as vision screening programmes have been shown to reduce the prevalence of amblyopia in society.

Another study design to assess the B4SC vision screening programme is randomly selecting a sample of children who receive screening from the B4SC, which is then assessed for VA and any ocular disease. This would allow calculation of the true values of sensitivity, specificity, PPV, and NPV. However, this study design does present an ethical issue, as it may identify children who have a visual deficit who passed the screening, and there may not be capacity to treat these children. Therefore, this study utilised retrospective data regarding who were already seen at an optometrist or DHB eye clinic, which did allow comparison of VA data between screening and follow up, calculation of PPV, estimations of sensitivity, specificity, and NPV, and

Another limitation of the study design was the time of the screening and follow up assessment. The study analysed children who were screened by the B4SC between 1 April and 30 September 2016. Follow up data for these children was obtained from optometrists, who regarding identifying details of all children seen aged 4 to 7 years, between 1 April and 31 October 2016, as well as data from DHB eye clinics for all children seen aged 4 to 7 years, between 1 April and 30
November 2016. This meant there was a month delay between the end of the B4SC screening period, and the end of the optometrist data recording period, and a two-month delay between the end of the B4SC screening period, and the end of the DHB eye clinic recording period. It is possible that this delay was not long enough to account for the time taken for a child to be referred from the B4SC and the parent to arrange appointment with an eye health care provider.

The major shortfall of this audit is the limited data. There were many children identified as failing the B4SC vision screening, but not identified as being seen at any DHB eye clinic or optometrist within the study period: 58% of children who failed vision screening. This does affect the accuracy of the calculations of the sensitivity, specificity, NPV, and PPV, particularly if there is some systematic difference in the visual statuses between children failing and being seen, and children failing and not being seen. Therefore, any future audit of the B4SC should ensure there is thorough follow up of as many cases of screening failure as possible.

7.4 Further Research needed

There have been several different areas for further research identified. This includes an alternative study design to precisely calculate NPV, sensitivity, and specificity of the B4SC vision screening programme. There is a need for research on the long-term outcomes of the B4SC, including measuring the risk difference of amblyopia for children who receive vision screening compared to those who do not. This can be used to quantify the cost-utility of the B4SC. Future research could also stratify screening data by SES, to determine the presence and size the effect of SES on vision status. There is also a lack of cross-sectional data on the prevalence of both refractive error and amblyopia, which would provide important information for health resource planning. Also, the emerging use of photoscreeners in various societies for childhood vision screening presents some opportunity for potential improvement in childhood vision screening, with their
auxiliary use in screening, and so exploration of the effectiveness of these in a New Zealand setting could be explored.

7.5 Key conclusions of this study

Amblyopia is a non-fatal condition, the functional impact of which is of some debate. Therefore, if there is to be a nationwide screening programme for amblyopia, it should be as accurate as possible, maximising the number of cases in society that are treated, and minimising the number of false referrals. The high NPV means that most cases of amblyopia will be identified in screening. The relatively low PPV, however, does mean that the vision screening is not performing as efficiently as possible, and may be generating extra public health care costs, with unnecessary referrals to DHB eye clinics.

There are concerningly high rates of not having been seen by optometrist or DHB after referral from the B4SC. This may be a true effect, which could be due to parents not making follow-up appointment after referral or could have been due to the study missing a significant number of children who were seen at optometry practices. This could be determined by following up with parents of children who were referred as to what was done regarding the child’s referral.

There are cost implications of DHB versus optometrist referral, given there is a low rate of optometry to ophthalmologist referral. Optometrists are managing most cases referred to them from the B4SC themselves, which means there is a reduced cost for the DHB in management of these children. However, this may imply an under-utilisation of orthoptists, who are highly trained allied health professional, and may mean there is opportunity for the improvement in the use of orthoptist referral pathways for optometrists in the management of some paediatric conditions, including amblyopia.

No children were identified in this study to have any ocular pathology, aside from refractive error, amblyopia, and strabismus. This could be due to: the
relatively rare instances of other eye pathology, and thus not occurring in any children included in this study; other pathologies being identified before vision screening by other means such as parents, GPs, or paediatricians detecting these pathologies; or due to the B4SC vision screening not being able to detect eye disease that may be present but does not affect visual acuity.

There were very low rates of medical and surgical management of children screened by the B4SC identified as having a reduced VA, which may have been due to medical and surgical management not being indicated for most cases of VA reduction identified. All cases of refractive error, and most cases of amblyopia involved conservative management with glasses. All occlusive therapy for amblyopia was with patching as opposed to atropinisation. The management of children with strabismus assessed and referred to the DHBs was not followed past the end of this study, but it is possible that these cases received medical or surgical treatment.

Most common childhood strabismus cases have already presented by the age when they are screened by the B4SC. This means that the B4SC vision screening perhaps occurring too late to be effective in detecting cases of strabismus, particularly accommodative esotropia. However, many of these cases are detected before vision screening occurs by other means, and vision screening is primarily for detecting cases of amblyopia. Therefore, missing numbers of strabismus cases is not a major downfall of the B4SC, but undiagnosed cases of strabismus may still be at risk of amblyopia development.

The VHT VA testing is accurate, and while it does underestimate the extent of a VA deficit at large VA deficits, and does have a high false positive rate, it is performing its function of identifying cases of reduced VA, without missing many cases.

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Appendix A

The B4 School Check: A Handbook for Practitioners

5 Vision Screening

National preschool vision screening protocols

Introduction

Prevalence of visual deficits in preschool population

The prevalence of visual deficits in the preschool population is estimated to be 10–15 percent (Feiglmeir 1998). The main clinically significant visual deficits include amblyopia, strabismus and refractive error.

Estimates of the prevalence of amblyopia are 1.2–5.6 percent. Amblyopia is potentially reversible, but for treatment to be beneficial it needs to be instituted before the child is seven years old (Feiglmeir 1998). New Zealand research suggests that treatment is most beneficial if started before the child is four years old (Hope, personal communication).

Effects of preschool vision screening on prevalence of visual problems

A cohort study reported by a Canadian task force examined the effects of preschool vision screening on the prevalence of visual problems 6–12 months after screening. At follow-up, the screened group had 50 percent fewer visual problems and 75 percent fewer severe visual problems than the unscreened group had, indicating that screening is effective. The study did not measure the impact of the visual problems and screening on school performance (Feldman, In Feiglmeir 1998).

One study demonstrated a negative predictive value of 98.7 percent for amblyopia, strabismus and high refractive errors, using visual inspection, assessment of visual acuity, and evaluation of stereopsis (Hartmann et al 2000). That is, a normal screen was highly likely to mean normal vision. A similar study demonstrated a positive predictive value of 72 percent, that is about three-quarters of children with an abnormal screen would have abnormal vision.

In contrast, the results of the Vision in Preschoolers study show conclusively that use of visual acuity screening alone (single optotype crowded Lea symbols) at 5 feet has a sensitivity of 0.87 for amblyopia and 0.79 for strabismus, which was not significantly increased by the addition of a stereopsis screen (Stereo-smile 2) (Vision in Preschoolers Group 2005). The addition of the stereoacuity screen increased test length and cost significantly. This group is due to report on the most appropriate screening modalities for preschool children.

Most commonly used acuity screen

The most commonly used acuity screen is one containing lines of letters (eg, the Snellen chart) or one in which single letters have neighboring 'confusion bars'. These two tests give comparative results. Where possible, one of these tests should be used when vision screening preschoolers.

The single-letter stimulus of the Perr Letter-Matching Test without confusion bars is an easier visual test and is appropriate for children who cannot perform the more complex tests.
When to initiate a full assessment

If you, a teacher or a parent or caregiver has concerns about a child’s vision or eyes, initiate a full assessment with a vision professional.

Screening test may not be necessary

If the child is currently under the care of an ophthalmic practitioner, a screening test is unnecessary, whether the child wears glasses or not.

Preschool children (four-year-olds)

Preschool vision tests are carried out in primary health care or community-based settings or in kindergarten or preschool sessions where the largest groups of four-year-olds can be targeted.

It is best to undertake the vision and hearing assessments together, but take care to ensure that children are not tired, as their responses will be less reliable.

If the vision and hearing tests are not done with the rest of the B4 School Check, it is better to do them earlier, so that any abnormal screen results can be discussed with the parents at the subsequent visit.

The Parr Letter-Matching Test with confusion bars has been used in the New Zealand context for initial vision screening of five-year-olds for many years. The comparative effectiveness and ease of use of the Lea Symbols test suggests that this test may be a better screen, and it will be assessed once the B4 School Check programme is underway.

New entrants and year 1 children (five- and six-year-olds)

New entrant vision tests are carried out within the child’s first year of school. This may be done as a catch-up screen of children who have not had their B4 School Check or as a follow-up for children with abnormal results in the B4 School Check.

Equipment needed for vision screening tests

For the vision screening tests, the tester needs:

- A 4 m Parr charts with and without confusion bars with key card or equivalent
  Sheridan Gardner charts
- A 4 m Snellen chart
- Occluding glasses or patch
- A retractable 5 m ruler
- Masking tape
- A light meter
- A chair for the child.
Test technique: Parr Letter-Matching Test (with or without confusion bars) or equivalent Sheridan Gardner charts

Setting for Parr Letter-Matching Test/Sheridan Gardner Charts Test
The Parr Letter-Matching Test requires a room that is:
- free of distractions and more than 4 m long
- uniformly and brightly illuminated, that is, with a light level of:
  - at least 300 lux in the room
  - about 500 lux to illuminate the text chart.
If you are unsure whether the lighting is sufficient, carry out a formal light meter test.
The test is conducted exactly 4 m from the child and at the same level as the child's eyes. Measure 4 m from the child with the tape measure, and mark the floor with a piece of masking tape.
Ensure that the test chart (book) and the 'key' card match (ie, both have confusion bars) and have a matte finish to ensure the child cannot see reflections.

Procedure for preparing the child for Parr Letter-Matching Test/Sheridan Gardner Charts Test
Follow these steps to prepare the child for the Parr Letter-Matching Test.
1. Seat the child so their eyes are level with the masking tape. Note: The front legs of the child's chair may be level of the tape.
2. Hold the key card close to and in front of the child. Explain to the child that you will be playing a simple game.
3. Show the child a letter shape from your book. Explain that they have to point to the shape that is the same on their card.
4. Flip the book to a large letter and gently lift the child's hand and place their finger on the matching letter.
5. Change the letter and again place the child's finger on the matching letter.
6. When you feel the child understands the task, show the child the eye patch and suggest they need to be a 'pirate' to play the game.
7. Follow the procedure for the Parr Letter-Matching Test.
Procedure for Parr Letter-Matching Test/Sheridan Gardner Charts Test

Follow these steps to undertake the Parr Letter-Matching Test.

1. Place the eye patch over the child's left eye.

2. Move to the 4 m point. Ensure no other children are sitting between you and the child being tested.

3. Beginning with the largest letter, show the child progressively smaller letters from each level. Encourage the child as much as possible. Continue until the child has difficulty identifying the letters.

4. Record the smallest letter size at which the child identified all letter shapes correctly. Use the conversion table on the back cover of the test book.

5. Place the eye patch over the child's right eye.

6. Move to the 4 m point.

7. Beginning with the largest letter, show the child progressively smaller letters from each level. Show the letters in a different order from that which you showed the child in step 3. Encourage the child as much as possible. Continue until the child has difficulty identifying the letters.

6. Record the smallest letter size at which the child identified all letter shapes correctly. Use the conversion table on the back cover of the test book.

NB: 6/6 6/6 is recorded when the child is shown all three 6/6 letters and can achieve 6. If the child is aged under four and cannot perform the test with confusion bars or makes inconsistent responses, repeat the test without confusion bars and record the result. Record the test situation without confusion bars in the result.

Test technique: Snellen Vision Test

Setting for Snellen Vision Test

The Snellen Vision Test requires a room that is:

- free of distractions and more than 4 m long
- uniformly and brightly illuminated, that is, with a light level of:
  - at least 300 lux in the room
  - about 500 lux to illuminate the test chart.

If you are unsure whether the lighting is sufficient, carry out a formal light meter test.

The test is conducted exactly 4 m from the child and at the same level as the child's eyes. Measure 4 m from the child with the tape measure, and mark the floor with a piece of masking tape.

Ensure that the test chart has a matte finish to ensure the child cannot see reflections.

Make sure the child is not facing a window or other bright light source that could make the chart difficult for them to see.
Procedure for preparing the child for Snellen Vision Test
Follow these steps to prepare the child for the Snellen Vision Test.

1. Stand the child behind the 4 m mark, with their toes on the masking-tape line.
2. Explain to the child that you will point to random letters on the chart and ask the child to identify each letter.
3. Ensure that the child knows the names of the letters.
4. Follow the procedure for the vision chart with the Snellen Vision Test.

Procedure for Snellen Vision Test
Follow these steps to undertake the Snellen Vision Test.

1. Place the occluder in position with the child’s right eye visible. Explain that the child is to hold the occluder in place until you ask them to move it.
2. Turn the eye chart over. Beginning with the largest letter, point to progressively smaller letters (two or three letters from each level is sufficient). Select letters randomly. Encourage the child as much as possible. Continue until the child has difficulty identifying the letters.
3. Record the smallest letter size at which the child identified all letters (i.e., the whole line) correctly.
4. Ask the child to turn the occluder over, so their left eye is visible.
5. Turn the eye chart over. Beginning with the largest letter, point to progressively smaller letters (two or three letters from each level is sufficient). Select letters randomly and in a different order from that in step 2. Encourage the child as much as possible. Continue until the child has difficulty identifying the letters.
6. Record the smallest letter size at which the child identified all letters (i.e., the whole line) correctly.

Pass, rescreen and refer criteria for Parr Letter-Matching and Snellen Vision Tests
See the clinical pathway and referral criteria in Figure 2.

Screening or referral unnecessary if child under ophthalmic practitioner’s care
If the child is under the ongoing care of an ophthalmic practitioner (an ophthalmologist or optometrist) and has been prescribed glasses:
• the child should not usually be screened
• if the child is screened, a referral is unnecessary no matter what the vision results are, but contact the parent or caregiver to provide them with the results and to make sure the child has had a recent vision examination.
Offer referral if concerns about child’s vision
If at any stage, a teacher, parent or caregiver thinks the child has any vision or development-related problems, it may be necessary to provide a vision screen, but there should also be an offer of a referral for the child’s eyes to be examined, as the screen does not cover some aspects of vision.

Pass, refer and rescreen criteria for vision screening at four years

Vision is 6/9 or better in both eyes at the B4 School Check
If the child’s vision is 6/9 or better in both eyes:
• the child’s vision screening test is considered a pass
• note the measurements of vision on the child’s records
• take no further action.

Vision is 6/9 in one eye and 6/6 in the other at the B4 School Check
If the child’s vision is 6/9 in one eye and 6/6 in the other:
• note the measurements of vision on the child’s record
• arrange a rescreen for three to six months’ time.

Vision is 6/12 or worse in either or both eyes at the B4 School Check
If the child’s vision is 6/12 or worse in either eye or both eyes, refer the child for an ophthalmic assessment according to local protocols.

On rescreen
If the child’s vision is 6/6 or better in both eyes the rescreen is considered a pass and no further action is required.

If there is no change in the child’s vision (i.e. they are 6/9 in one eye and 6/6 in the other) or their vision has become worse in either eye (i.e. they are 6/9 in both eyes, or 6/12 or worse in either eye) refer the child for an ophthalmic assessment according to local protocols.

Referral pathways

Follow local protocols
Referral pathways depend on the local availability of orthoptist, optometric or ophthalmologist services in the District Health Board (DHB).

A national protocol for vision screening referral is being developed with stakeholders. Until the national protocol is in place, local protocols must provide a rapid, clinically appropriate care pathway that ensures rapid referral and minimises the cost to the family/whānau. In general, if DHB orthoptists are available these should generally be the first contact in the referral pathway.
Some areas may have a waiting time for a specialist assessment in a hospital eye department. In this situation, refer the child for a GP assessment or inform the child’s parent or caregiver about services available from local optometrists.

Subsidies for glasses/spectacles

Children with vision problems, aged 15 years and under, who are in low income families may be able to get funding assistance for examinations, frames, lenses, eye patches and repairs. The child will need to have an assessment by a vision assessor who is registered as an assessor for this subsidy. The accredited vision assessor will assess a child’s vision needs and may recommend glasses or other vision equipment.

An accredited assessor is usually an optometrist, eye specialist or a service co-ordinator for the Royal New Zealand Foundation of the Blind. Not all optometrists and eye specialists are accredited vision assessors. You should have an up-to-date list of accredited assessors.

If the child requires a referral and their parent has a Community Services Card, advise the parent to contact Enable New Zealand to find a vision assessor in their area (phone 0800 17 1981).

Figure 2: Vision screening clinical pathway and referral criteria

The pass, refer and rescreen criteria for five year olds can be located on page 29 of the National Protocols available on the Ministry of Health website (www.moh.govt.nz/moh.nzl/indexmh/vision-and-hearing-screening-protocols-nov09).
# Appendix B

## Optometry Data Sheet for VHT Study

1 April to 31 October 2016

**Date Seen:** ___________________

### Demographic Details:

<table>
<thead>
<tr>
<th>Name</th>
<th>Date of Birth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Address</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

### Source of Referral:

- VHT ☐
- GP ☐
- Parent ☐
- Teacher ☐

### Unaided Visual Acuity:

<table>
<thead>
<tr>
<th>Right eye: ____</th>
<th>Left eye: ____</th>
</tr>
</thead>
</table>

### Best Corrected Visual Acuity:

<table>
<thead>
<tr>
<th>Right eye: ____</th>
<th>Left eye: ____</th>
</tr>
</thead>
</table>

### Test Used:

- Snellen Chart ☐
- Parr Letter Matching ☐
- Lea Symbols ☐
- Other ☐

### Presence of Amblyopia:

- yes/no (please circle one)

(Note: For this study, amblyopia is defined as a VA of 6/12 in either eye, or a two line difference or greater between eyes)

### Presence of Refractive Error:

- yes/no (please circle one)
**Ophthalmic Examination:**

- Cycloplegic Refraction
- Any Pathology (briefly describe)

**Management:**

- Glasses
- Patching
- Ophthalmology Referral
- Discharge