A VISUAL PROFILE OF QUEENSLAND INDIGENOUS AND NON-INDIGENOUS SCHOOL CHILDREN, AND THE ASSOCIATION BETWEEN VISION AND READING

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Keywords

Aboriginal and Torres Strait Islander population, accommodation, accommodation and/or vergence disorders, astigmatism, binocular vision, convergence insufficiency, colour vision, heterophoria, hyperopia, myopia, rapid automated naming, reading ability, refractive error, strabismus, vision impairment, vision screening, visual acuity, visual function, visual information processing and visual motor integration.
Abstract

Background/aims: The gap in reading and numeracy between Australian Indigenous and non-Indigenous children is well documented. While a number of vision conditions have been associated with reduced reading ability in non-Indigenous populations, the prevalence of these vision conditions and the link with reading ability is unknown in Australian Indigenous children. In particular, refractive error, strabismus, accommodation and/or vergence disorders and colour vision deficiency, and their potential association with reading ability, have not been investigated in detail in this group. Understanding the prevalence of those vision conditions and their potential impact on reading ability would assist in ensuring adequate resources are available for detecting and managing these conditions in Indigenous children. Vision screenings are one method for detecting potential vision problems in this group; however, in Australia, there is little information regarding the coverage and nature of current children’s vision screenings. The main aim of the current research was to characterise the visual profile of Queensland Indigenous children and to determine the link between vision conditions and reading ability in this population. A secondary aim was to evaluate vision screening services in Queensland in terms of their coverage and their ability to detect vision conditions in this group. Prior to the main study, a preliminary study was also performed to determine the most appropriate method for measuring refractive error in children, both in terms of the ability of the technique to control accommodation as well as its repeatability.

Methods: Twenty five school children aged between six and thirteen years (mean age: 9.52 years ± 2.06) were recruited for the preliminary study. Refractive error was measured at the Queensland University of Technology Optometry clinic using retinoscopy and autorefraction under both cycloplegic and non-cycloplegic conditions.

For the main study, five hundred and ninety five school children (181 Indigenous and 414 non-Indigenous) from Years 1, 2, 6 and 7 from nine participating primary schools were recruited. A series of tests were administered, including visual acuity, refractive error assessed with cycloplegic retinoscopy, binocular vision...
testing, and the assessment of visual information processing skills and reading ability. The prevalence of vision conditions such as refractive error, strabismus, accommodation and/or vergence disorders, colour vision deficiency and impaired visual information processing skills in the Indigenous children was determined, and compared to that of their non-Indigenous peers. In addition, the association between uncorrected hyperopia, convergence insufficiency (CI), reduced rapid automatised naming (RAN) and delayed visual motor integration (VMI) skills with reduced reading ability was investigated in Indigenous and non-Indigenous children, as this link has been reported previously in children from the wider population.

In the final component of the research, two cross-sectional surveys were used to evaluate the vision screening services available to Queensland children. One survey was distributed to nurses and the second to Queensland optometrists. Eighty eight surveys were completed by nurses and 159 were completed by optometrists. The surveys included questions that asked whether the nurses and optometrists had been involved in vision screenings, the location of the screenings, tests performed and referral criteria adopted.

**Results:** Findings from the preliminary study demonstrated that cycloplegic retinoscopy was the best technique for measuring refractive error in children, based on its ability to control accommodation, as well as its repeatability. This technique was thus used for the main study.

A visual profile of Queensland Indigenous primary school children was determined. Indigenous children had less refractive error (9.6% compared with 16.1%) and strabismus (none compared with 3.0%) than their non-Indigenous peers. There was no difference in the prevalence of colour vision deficiency or reduced visual acuity (unaided or presenting) between the two groups. CI however, was twice as common in Indigenous children (10.3% compared with 5.2%). VMI skills were lower in Indigenous children and more Indigenous children had reduced RAN skills. This is particularly important given the association between accommodation and/or vergence disorders, delayed visual information processing skills and reduced reading ability in the general population.

Reading outcomes were also different between groups with Indigenous children scoring significantly lower in reading accuracy in both age groups (Years 1 – 2 and Years 6 – 7); Indigenous children in the younger age group also scored lower
in reading comprehension. Reduced RAN and VMI skills were significantly associated with reduced reading ability in both Indigenous and non-Indigenous children.

The final component of the research revealed that a number of health service districts within Queensland have a very low provision of children’s vision screening services. Furthermore, there is no uniform battery of tests used in children’s vision screenings by nurses or optometrists. While the majority of vision screenings measured visual acuity and screened for strabismus, the specific tests used varied between survey respondents. A large number of optometrists also included colour vision and stereoacuity tests as part of the screening. Additional tests of binocular vision, visual information processing and/or ocular health were performed by only a small number of nurses and optometrists. Little agreement also existed between optometrists and nurses in terms of the referral criteria and in a number of cases the referral criteria were not appropriate.

Conclusions: This research is the first to comprehensively assess a range of vision characteristics in a large group of Indigenous and non-Indigenous children. The prevalence of a number of vision conditions in Queensland Indigenous children is reported for the first time. The main findings were that Indigenous children have less vision impairment, refractive error and strabismus; yet CI is twice as common. This is particularly important given that accommodation and/or vergence disorders have been associated with educational outcomes, and CI can result in asthenopia, reduced concentration and avoidance of near tasks. Reduced VMI and RAN skills were also more common in Indigenous children. The effect of vision conditions on reading was also investigated, with RAN and VMI being associated with reduced reading ability in Indigenous and non-Indigenous children.

This research is also the first to document the coverage of existing vision screening programs across Queensland by nurses and optometrists; as well as investigate the battery of tests performed in screenings and the associated referral criteria. The findings indicate that current vision screening programs need to be more coordinated and structured with appropriate standardised protocols if they are to detect paediatric vision conditions common in Indigenous and non-Indigenous children.
Collectively, these findings suggest the need for future research to investigate what proportion of Indigenous children with CI are symptomatic or alternatively, avoiding near tasks. In particular it would be extremely useful to explore whether treatment of CI results in an improvement in reading ability as this would have significant implications for the academic capacity of this population. This is important given that CI is twice as common in Indigenous children and this group also has poorer reading outcomes. The impact of other accommodation and/or vergence disorders on reading outcomes in Australian Indigenous and non-Indigenous children should also be investigated. As well, determining the effect of training VMI and RAN on reading outcomes in this group would be highly beneficial.

More work is required also to develop the vision screening service delivery model that has been proposed in this research for nurses and optometrists. This will provide a more standardised and coordinated approach to children’s vision screenings across the state of Queensland, with the potential for broader application across Australia, as well as across other health services.
Publications and Presentations

Refereed publications


Conference presentations


Honours received in the course of this work

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# Table of Contents

Keywords ................................................................................................................................................. i  
Abstract .................................................................................................................................................. ii  
Publications and Presentations ............................................................................................................... vi  
Table of Contents ........................................................................................................................................ vii  
List of Figures ........................................................................................................................................... ix  
List of Tables ............................................................................................................................................ x  
List of Abbreviations ............................................................................................................................... xiii  
Statement of Original Authorship ........................................................................................................... xv  
Acknowledgments .................................................................................................................................... xvi  

## CHAPTER 1: INTRODUCTION ....................................................................................................... 1  
1.1 Background .................................................................................................................................. 1  
1.2 Context ......................................................................................................................................... 2  
1.3 Purposes ....................................................................................................................................... 3  
1.4 Significance, Scope and Definitions ............................................................................................ 4  
1.5 Thesis Outline .............................................................................................................................. 6  

## CHAPTER 2: LITERATURE REVIEW ......................................................................................... 11  
2.1 Disparity in health outcomes between Indigenous and non-Indigenous Australians ................. 11  
2.2 Literacy and numeracy skills of Australian Indigenous children ............................................... 13  
2.3 Vision conditions and their association with reading ability ..................................................... 16  
2.4 Vision conditions in Australian Indigenous children ................................................................. 29  
2.5 Vision screenings in Australia ................................................................................................... 33  
2.6 Summary and Implications ........................................................................................................ 37  

## CHAPTER 3: VALIDATION OF CYCLOPLEGIC RETINOSCOPY FOR MEASUREMENT  
OF REFRACTIVE ERROR ........................................................................................................... ... 39  
3.1 Refraction in children: a comparison of two methods of accommodation control .................... 40  
3.2 Repeatability of retinoscopy and autorefraction in children ...................................................... 51  
3.3 Conclusion .................................................................................................................... ............. 62  

## CHAPTER 4: VISUAL PROFILE OF QUEENSLAND INDIGENOUS CHILDREN .......... 63  
4.1 Background ................................................................................................................................ 63  
4.2 Research Design ......................................................................................................................... 63  
4.3 Results ........................................................................................................................................ 83  
4.4 Discussion ................................................................................................................................ 104  
4.5 Conclusion .................................................................................................................... ........... 114  

## CHAPTER 5: VISION CONDITIONS AND THEIR ASSOCIATION WITH READING ...... 117  
5.1 Background ................................................................................................................................ 117  
5.2 Research Design ......................................................................................................................... 118
A visual profile of Queensland Indigenous and non-Indigenous school children, and the association between vision and reading

5.3 Results ......................................................................................................................................................... 121
5.4 Discussion .................................................................................................................................................... 139
5.5 Conclusion .................................................................................................................................................... 144

CHAPTER 6: VISION SCREENING SERVICES IN QUEENSLAND ........................................................................ 147

6.1 Background .................................................................................................................................................. 147
6.2 Aim ............................................................................................................................................................... 147
6.3 Research Design ......................................................................................................................................... 147
6.4 Analysis ....................................................................................................................................................... 152

CHAPTER 7: CONCLUSIONS .......................................................................................................................... 175

BIBLIOGRAPHY .................................................................................................................................................. 183

APPENDICES ...................................................................................................................................................... 205
List of Figures

Figure 1.5-1. Schematic of research program..............................................................................................................9

Figure 2.1-1. Gap in life expectancy between Indigenous and non-Indigenous Australians
(Australian Parliament House website, 2009)........................................................................................................11

Figure 2.1-2. Australia’s population distribution by age group and Indigenous status
(Australian Government, 2010).................................................................................................................................12

Figure 3.1-1. Most plus spherical power results for retinoscopy and autorefraction......................47

Figure 3.2-1. Mean versus standard deviation for the five repeat measures recorded for each participant with non-cycloplegic retinoscopy........................................................................................................57

Figure 3.2-2. Mean versus standard deviation for the five repeat measures recorded for each participant with cycloplegic retinoscopy........................................................................................................57

Figure 3.2-3. Mean versus standard deviation for the five repeat measures recorded for each participant with non-cycloplegic autorefraction........................................................................................................58

Figure 3.2-4. Mean versus standard deviation for the five repeat measures recorded for each participant with cycloplegic autorefraction........................................................................................................58

Figure 4.2-1. LEA symbols logMAR chart......................................................................................................................69

Figure 4.2-2. Randot stereotest ..................................................................................................................................73

Figure 4.2-3. Distance and near Howell-Dwyer phoria cards..................................................................................75

Figure 4.2-4. Vision tests performed at each testing station ..................................................................................82

Figure 4.3-1. Spread of spherical refractive error data by Indigenous status.........................................................89

Figure 4.3-2. Range of spherical refractive errors for Indigenous and non-Indigenous children (%)................................................................................................................................................90

Figure 4.3-3. Percentage of Indigenous and non-Indigenous children with different levels of distance heterophoria...............................................................................................................................................95

Figure 4.3-4. Percentage of Indigenous and non-Indigenous children with different levels of near heterophoria...............................................................................................................................................96

Figure 4.3-5. Percentage of children with a reduced positive fusional vergence result (at near)........97

Figure 4.3-6. Percentage of children with a reduced negative fusional (at near)................................................98

Figure 5.3-1. Distribution of reading accuracy percentile scores by Indigenous status. Top figure - Years 1 and 2 children; bottom figure - Years 6 and 7 children...........................................................................123

Figure 5.3-2. Distribution of reading comprehension percentile scores by Indigenous status.
Top figure - Years 1 and 2 children; bottom figure - Years 6 and 7 children.........................................................124

Figure 6.3-1. Queensland Health Service Districts (The State of Queensland (Queensland Health), 2012).................................................................................................................................149

Figure 6.4-1. Schematic of proposed vision screening service delivery model ..............................................170
List of Tables

Table 2.2-1 Queensland 2011 NAPLAN results: percentage of children reaching the minimum national standard in reading and numeracy (Australian Curriculum Assessment and Reporting Authority, 2011) .................................................................13

Table 2.2-2 Percentage of Year 7 Indigenous children reaching the minimum national standard (Ministerial Council on Education Employment Training and Other Youth Affairs, 2007) ........................................................................................................14

Table 2.2-3 Percentage of Year 7 Indigenous and non-Indigenous children meeting the minimum national standard in reading and writing, 2008 – 2011 (Australian Curriculum Assessment and Reporting Authority, 2011) ..................................................15

Table 2.5-1 Tests included in the Orinda MCT ..................................................................................................................35

Table 3.2-1 Group mean spherical power measurements for each testing condition .......................................................55

Table 3.2-2 Intraclass correlation coefficient (ICC) and repeatability coefficients for retinoscopy and autorefraction (non-cycloplegia and cycloplegia) ..........................................................................................56

Table 4.2-1 Dependent variables used in the analysis ......................................................................................................65

Table 4.2-2 Refractive error classification system used in the Sydney Myopia Study (Huynh et al., 2006; Ip, Robaei, et al., 2008; Ojaimi, Rose, Smith, et al., 2005) .................................................................71

Table 4.2-3 Refractive error classification used in the current study ..................................................................................72

Table 4.2-4 Classification for reduced fusional vergence ranges ......................................................................................77

Table 4.2-5 Factors used for classification of different accommodation and/or vergence disorders ..............................................79

Table 4.3-1 Number of children (%) grouped by Indigenous status, age group, gender and region. Chi-square tests for age group, gender and region are shown with significant results in bold text .........................................................................................................................84

Table 4.3-2 Responses to parental questionnaire. Numbers in brackets represent the number of responses that were ‘yes’ over the total number of responses submitted for each question. Chi-square tests for each question by Indigenous status are shown with significant results in bold text ........................................................................................................86

Table 4.3-3 Number of children (%) presenting with different levels of vision impairment (based on reduced habitual visual acuity), by Indigenous status .................................................................................................88

Table 4.3-4 Prevalence of refractive error (%) by Indigenous status .....................................................................................90

Table 4.3-5 Contribution of different explanatory variables for each of the different refractive errors: hyperopia, myopia, astigmatism and anisometropia. Most parsimonious model from each step-wise regression is presented ...........................................................................................................91

Table 4.3-6 Percentage of children with clinically significant refractive error in at least one eye who reported having spectacles .........................................................................................................................92

Table 4.3-7 Mean scores obtained for binocular vision tests. Results from t-tests comparing the Indigenous and non-Indigenous groups are shown, and significant findings are in bold text ..................................................................................................................93

Table 4.3-8 Percentage of Indigenous and non-Indigenous children with normal, reduced and very reduced accommodative facility .................................................................................................................98

Table 4.3-9 Percentage of Indigenous and non-Indigenous children with accommodation and/or vergence disorders; significant differences are in bold text .........................................................................100
A visual profile of Queensland Indigenous and non-Indigenous school children, and the association between vision and reading
Table 6.4-2 Number of responses by nurses and optometrists for each HSD, as well as the percentage involved in vision screenings. Bold responses indicate the HSDs where more than half of the respondents were involved in screenings.................................154

Table 6.4-3 Number of nurses and optometrists who performed vision screenings, by location........156

Table 6.4-4 Percentage of nurses and optometrists that performed specific vision tests in children’s vision screenings .................................................................................................................................159

Table 6.4-5 Referral criteria used by optometrists and nurses for the different screening tests........164

Table 6.4-6 Pass/fail criteria for different stereoacuity tests .................................................................166

Table 6.4-7 Vision screening tests and referral criteria – Queensland Health Child and Youth Health Practice Manual .......................................................................................................................167
# List of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>ABS</td>
<td>Academic Behaviour Survey</td>
</tr>
<tr>
<td>AC/A</td>
<td>Accommodative convergence to accommodation ratio</td>
</tr>
<tr>
<td>ATSI</td>
<td>Aboriginal and/or Torres Strait Islander</td>
</tr>
<tr>
<td>BI</td>
<td>Base in</td>
</tr>
<tr>
<td>BO</td>
<td>Base out</td>
</tr>
<tr>
<td>CI</td>
<td>Convergence insufficiency</td>
</tr>
<tr>
<td>CIRS</td>
<td>Convergence Insufficiency and Reading Study</td>
</tr>
<tr>
<td>CITT</td>
<td>Convergence Insufficiency Treatment Trial</td>
</tr>
<tr>
<td>COAG</td>
<td>Council of Australian Governments</td>
</tr>
<tr>
<td>CVD</td>
<td>Colour vision deficiency</td>
</tr>
<tr>
<td>CYHP</td>
<td>Child and Youth Health Practice</td>
</tr>
<tr>
<td>DEM</td>
<td>Developmental Eye Movement (test)</td>
</tr>
<tr>
<td>GP</td>
<td>General practitioner</td>
</tr>
<tr>
<td>HKC</td>
<td>Healthy Kids Check</td>
</tr>
<tr>
<td>HSD</td>
<td>Health Service District</td>
</tr>
<tr>
<td>ICC</td>
<td>Intraclass correlation coefficient</td>
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<tr>
<td>MCT</td>
<td>Modified Clinical Technique</td>
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<tr>
<td>MIO</td>
<td>Monocular indirect ophthalmoscope</td>
</tr>
<tr>
<td>NAPLAN</td>
<td>National Assessment Program – Literacy and Numeracy</td>
</tr>
<tr>
<td>NCVSP</td>
<td>National Children’s Vision Screening Project</td>
</tr>
<tr>
<td>NIEHS</td>
<td>National Indigenous Eye Health Survey</td>
</tr>
<tr>
<td>NFV</td>
<td>Negative fusional vergence</td>
</tr>
<tr>
<td>NPC</td>
<td>Near point of convergence</td>
</tr>
<tr>
<td>NT</td>
<td>Northern Territory (Australian territory)</td>
</tr>
<tr>
<td>Acronym</td>
<td>Full Form</td>
</tr>
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</tr>
<tr>
<td>NTEHP</td>
<td>National Trachoma Eye Health Project</td>
</tr>
<tr>
<td>NYSOA</td>
<td>New York State Optometric Association</td>
</tr>
<tr>
<td>OAA</td>
<td>Optometrists Association Australia</td>
</tr>
<tr>
<td>PAG</td>
<td>Project advisory group</td>
</tr>
<tr>
<td>PFV</td>
<td>Positive fusional vergence</td>
</tr>
<tr>
<td>QLD</td>
<td>Queensland (Australian state)</td>
</tr>
<tr>
<td>RAN</td>
<td>Rapid automatised naming</td>
</tr>
<tr>
<td>RANZCO</td>
<td>Royal Australian and New Zealand College of Ophthalmologists</td>
</tr>
<tr>
<td>RESC</td>
<td>Refractive Error Study in Children</td>
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<tr>
<td>VIP</td>
<td>Visual information processing</td>
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<tr>
<td>VMI</td>
<td>Visual motor integration</td>
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Statement of Original Authorship

The work contained in this thesis has not been previously submitted to meet requirements for an award at this or any other higher education institution. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made.

Signature: QUT Verified Signature

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Chapter 1: Introduction

1.1 BACKGROUND

Australian Indigenous adults have a higher prevalence of low vision (<6/12) and blindness (<6/60) compared with non-Indigenous Australians (Taylor et al., 2009; Wolf & Bowers, 1999; Wright, Keefe, & Taylor, 2009), however, vision impairment and common paediatric vision conditions in Indigenous children is largely unknown.

Trachoma has been the primary focus of the limited number of studies that have examined the vision and/or ocular health of Australian Indigenous children (Ewald, Hall, & Franks, 2003; Laming, Currie, & DiFrancesco, 2000; Lansingh, Weih, Keefe, & Taylor, 2001). While the prevalence of refractive error, colour vision deficiency, strabismus, amblyopia and accommodation and/or vergence disorders – all of which are routinely screened and/or tested for in children’s eye examinations in the wider population – has not been established.

This is important given that a number of these conditions have been associated with reduced academic performance in school children. In particular, uncorrected hyperopia, accommodation and/or vergence disorders and delayed visual information processing skills have all been associated with reduced educational outcomes (Chen, Bleything, & Lim, 2011; Garber, 1981; Godts, Smeets, Evans, & Tassignon, 1999; Goldstand, Koslowe, & Parush, 2005; Kattouf & Steele, 2000; Krumholtz, 2000; Kulp & Schmidt, 1996; O’Grady, 1984; Palomo-Alvarez & Puell, 2008, 2009; Rosner & Rosner, 1997; Shankar, Evans, & Bobier, 2007; Shin, Park, & Park, 2009; Williams, Latif, Hannington, & Watkins, 2005; Woodrome & Johnson, 2009).

The gap in literacy and numeracy skills between Indigenous and non-Indigenous school children is well known, with Indigenous children scoring lower than their non-Indigenous peers (Australian Curriculum Assessment and Reporting Authority, 2011). Given this disparity, it is important to know the prevalence of vision conditions that have been linked with reduced educational performance in the wider population in Australian Indigenous children, as well as determining whether these vision conditions are associated with reduced reading outcomes in this group.
This will assist in ensuring adequate resources are available for detecting and managing these conditions in Indigenous children.

Vision screenings provide a method for detecting potential vision problems in children who may otherwise not present for, or have access to, routine eye examinations; such as Indigenous children living in rural and remote areas. However, little is known about the characteristics of current vision screening programs available to Queensland children. Vision conditions that have been linked with educational outcomes should be screened for in school children, and screenings should be customised to the population being screened. Understanding the visual profile of Australian Indigenous children will:

- Allow for specific tailoring of vision screenings to target those conditions common in this group of children;
- Determine whether vision conditions associated with reduced educational performance are prevalent in Indigenous children, and should subsequently be screened for in this population.

1.2 CONTEXT

The gap in reading ability between Australian Indigenous and non-Indigenous children has been emphasised in national reports and has been the focus of a series of federal government initiatives (Collins, 1999). Fewer Indigenous children are meeting minimum national standards in literacy and numeracy compared with non-Indigenous children. For example, only 80% of Year 7 Indigenous children in Queensland reached the minimum national standard in reading, compared with 95% of non-Indigenous children (Australian Curriculum Assessment and Reporting Authority, 2011). Reducing this gap was one of the targets commissioned by the Council of Australian Governments (COAG) in 2009.

The discrepancy in reading ability between Indigenous and non-Indigenous school children may arise from a number of factors. Thus determining the prevalence of those factors known to impact on children’s reading ability in an Indigenous population would be highly informative. A number of vision conditions such as uncorrected hyperopia, accommodation and/or vergence disorders and visual information processing dysfunction have been shown to be associated with reduced reading ability in children in the wider community. However, the prevalence of
these vision conditions in Australian Indigenous children and their association with reading ability has not been investigated.

Timely detection of potential vision problems in Indigenous children is also critical, especially given that the accessibility of eye care services available to the Australian Indigenous community is not consistent across Australia (Turner, Xie, Arnold, & Taylor, 2011). Information regarding which vision screening services are currently available to Indigenous school children is necessary in order to ensure that this group is not marginalised in terms of detection and potential remediation of vision problems. It is equally important that these vision screenings target the conditions common in Indigenous children, as well as conditions that have been associated with reduced reading performance in the broader community. With almost 40% of the Indigenous population currently under the age of 15, more attention needs to be focussed on this sector of the Australian Indigenous population (Australian Government, 2010).

1.3 PURPOSES

The research project had three main aims:

- To develop a visual profile of Queensland Indigenous children by determining the prevalence of refractive error, colour vision deficiency, strabismus, accommodation and/or vergence disorders and delayed visual information processing skills in this population;

- To determine whether vision conditions that have been linked with reduced reading ability are more prevalent in Indigenous children, and to investigate whether these conditions are associated with reading ability in Queensland Indigenous and non-Indigenous children;

- To establish which vision screening services are currently available to Indigenous and non-Indigenous school children in Queensland; and to determine whether existing vision screening services target conditions that are more prevalent in Indigenous children, as well as conditions that may impact negatively on school performance.
1.3.1 KEY RESEARCH QUESTIONS

A series of key research questions were addressed as part of the research:

- What is the prevalence of refractive error, colour vision deficiency, strabismus, accommodation and/or vergence disorders and delayed visual information processing skills in Queensland Indigenous children?
- How does the prevalence of these vision conditions vary between Indigenous and non-Indigenous children from the same schools?
- Are deficits in these visual characteristics associated with reduced reading ability in Queensland school children?
- What is the coverage of current vision screening services available to Queensland school children by nurses and optometrists?
- Are existing vision screening services targeting conditions common to Indigenous and non-Indigenous school children? Do screening services target vision conditions that have been associated with reduced educational performance?
- Which tests are performed in vision screenings to detect these vision conditions? What are the referral criteria?

1.4 SIGNIFICANCE, SCOPE AND DEFINITIONS

The visual profile of Australian Indigenous children has not been characterised systematically to date. Apart from visual acuity measurements and trachoma grading, there has been only limited research to quantify the prevalence of refractive errors, strabismus, colour vision deficiency, accommodation and/or vergence disorders and visual information processing dysfunction in this population. It is important to address this deficiency in the literature by determining the prevalence of these conditions in Indigenous children compared with their non-Indigenous peers, as well as determining whether these conditions are associated with the established poorer reading outcomes of Indigenous children given that some of these visual factors have already been associated with lower academic achievement in children in the wider community.

It is essential to detect vision conditions in school children as early as possible so as to treat the visual symptoms associated with the condition and to minimise any
negative effect the untreated condition may have on the child’s reading and academic performance. Vision screenings can detect potential vision problems in children. Understanding the provision of current vision screening services to Queensland Indigenous and non-Indigenous children as well as the nature of the screenings, that is, their ability to detect conditions important to both Indigenous and non-Indigenous children, is critical to ensure that there are no regions being under- or over-serviced. Optometrists, school teachers and other health professionals will benefit from knowing which vision screening programs are available to Queensland children.

In this research project, a series of vision tests and a test of reading ability were performed on Indigenous and non-Indigenous primary school children in Years 1, 2, 6 and 7 from a range of metropolitan and rural schools in Queensland and this comprised the main study. The tests included measures of visual acuity, refractive error, colour vision, binocular vision function, visual information processing skills and reading ability. The association between visual function and reduced reading ability was also determined.

A preliminary study was performed prior to the main study to determine the most appropriate technique for measuring refractive error in children. This was based on the ability of the technique to effectively control accommodation, as well as its repeatability.

An online survey was also created for Queensland optometrists and a mailed survey was distributed to Queensland Health clinical nurse consultants. The information gathered from these surveys was used to characterise the provision of vision screening services to Queensland primary school children, the personnel who performed the screenings, the vision tests included and referral criteria used.

The appropriateness of current school vision screenings in Queensland in terms of the vision conditions targeted was also assessed. This assessment was based upon the visual profile determined in Queensland Indigenous (and non-Indigenous) school children in the first stage of this research project, as well as which conditions were found to be associated with reduced reading ability in Queensland school children.

1.4.1 DEFINITIONS

- ‘Indigenous’ describes the Australian Aboriginal and Torres Strait Islander (or ATSI) population;
• ‘Accommodation and/or vergence disorders’ describes the following diagnostic classifications: convergence insufficiency and excess, accommodative insufficiency and excess, basic esophoria and basic exophoria, and divergence insufficiency and excess. The individual parameters of near point of convergence, heterophoria assessment, fusional vergence range, stereoacuity and the presence of strabismus were measured to assess for accommodation and/or vergence disorders as well as binocular vision function;

• ‘Visual information processing skills’ for the purpose of this project covers the following perceptual sub-skills: visual spatial awareness, visual analysis, visual memory, visual sequential memory, visual motor integration (VMI) and rapid automatised naming (RAN). Many other skills can be classified under this heading, but were not considered for this project;

• ‘Vision screening’ describes a set of tests that are used to detect the likelihood of a defined vision condition. A vision screening is not designed to be diagnostic. A comprehensive eye examination is indicated after a failed vision screening to diagnose any suspected vision conditions.

1.5 THESIS OUTLINE

Chapter 2 comprises a review of the literature on the visual profile of the Australian Indigenous population, with particular emphasis on children. A review of reading skills of Indigenous and non-Indigenous children is also presented which highlights the achievement gap between the two groups. Chapter 2 further reviews the literature on the association between specific visual conditions and reduced reading and/or academic ability in school children in general (not Indigenous children specifically). This chapter serves to establish the framework for the selection of visual conditions assessed in the research in terms of their effect on reading ability.

Three separate studies were completed as part of the research program and are presented in this thesis. The remainder of this section describes the framework on which the three studies were based as well as provides an overview of how each study was designed to address the following research aims:
- Create a visual profile of Queensland Indigenous children by determining the prevalence of refractive error, colour vision deficiency, strabismus, accommodation and/or vergence disorders and delayed visual information processing skills in this group;

- Investigate the association between specific vision conditions and reading ability in Queensland Indigenous and non-Indigenous children;

- Evaluate the vision screening services available to Queensland Indigenous and non-Indigenous school children in terms of their coverage across the state of Queensland as well as their ability to detect common paediatric vision conditions and conditions that have been associated with reduced academic outcomes.

The main study was a large field-based study and was designed to address the first two research aims. Data collection took place at nine primary schools across Queensland, and vision and reading ability were measured in both Indigenous and non-Indigenous children. During the design stage of the main study, it became evident that a separate investigation was required prior to this study in order to establish the most appropriate method for measuring one of the visual parameters, refractive error in this population. This need arose because a review of the literature indicated that many different methods have been used to measure refractive error in paediatric refractive error studies, varying in terms of the test used, and the technique performed to control accommodation. A preliminary study was therefore designed to determine the most appropriate method for measuring refractive error in primary school children.

The preliminary study evaluated the ability of different refractive error measurement techniques to adequately control accommodation as well as the repeatability of the technique; as these are two separate factors important in the determination of refractive error in children. A detailed description of the methodology for this component of the research is presented in Chapter 3. The results of the findings relating to accommodation control have been published in the Optometry and Vision Science journal (Chapter 3.1), and the results relating to the repeatability of the technique are included in a journal article, which is currently under review (Chapter 3.2). An additional literature review has been included in Chapter 3 which evaluates the current literature on refractive error measurement.
techniques in children (and not Chapter 2), as the review was written for the purpose of the two papers, and does not directly address the research aims of the current thesis.

The main study was a large field-based study and the methods and results of this study were presented in Chapters 4 and 5. Chapter 4 comprises the methods that were used for the main study as well as the findings that relate to the development of the visual profile of Indigenous children. Chapter 5 presents the results and discussion relevant to the second research aim, that is, investigating the association between specific vision conditions and reduced reading ability.

The final study that completed this research program was a survey study designed to evaluate children’s vision screening services in Queensland. Two surveys were created and distributed to optometrists and nurses, the two health professions identified as being most active in vision screenings. Chapter 6 discusses the methodology for this survey study in detail, as well as presenting the results and a discussion. An extensive literature review on children’s vision screenings was also performed as part of this survey study. This literature review was published in the journal, Clinical and Experimental Optometry (Appendix A).

In summary, three separate studies were designed and performed as part of this thesis, see Figure 1.5-1. Chapters 3 – 6 provide a detailed description of the methodology used for each of these studies, the findings from the studies and a discussion. The preliminary study is presented first (Chapter 3), as results from this study shaped the methodology of the main study. The main study addressed research aims one and two, and each aim is presented in its own chapter (Chapters 4 and 5). The survey study ran concurrently to the main study, and is presented in Chapter 6.

Finally, Chapter 7 presents a summary of the main findings of this research project and includes a discussion of limitations of the presented findings, and recommendations for future research.
Chapter 1: Introduction

Survey study (Chapter 6)
- 88 nurses and 159 optometrists participated
- Aim: to assess the coverage of vision screening services to Queensland children and their ability to detect vision conditions important to Indigenous and non-Indigenous children

Main study (Chapters 4 and 5)
- Conducted at nine primary schools
- 595 school children participated
- Aim: to develop a visual profile for Indigenous children and to assess the association between vision conditions and reading

Preliminary study (Chapter 3)
- Conducted at QUT Optometry Clinic
- 25 school children participated
- Aim: to determine most appropriate method for measuring refractive error in children

Figure 1.5-1. Schematic of research program
Chapter 2: Literature Review

2.1 DISPARITY IN HEALTH OUTCOMES BETWEEN INDIGENOUS AND NON-INDIGENOUS AUSTRALIANS

The gap in health status between Indigenous and non-Indigenous Australians is well established and is epitomised by a difference in life expectancy of between 16 – 17 years, which has not reduced despite a number of initiatives over many years (Australian Institute of Health and Welfare, 2010). Figure 2.1-1 provides a snapshot of the gap in life expectancy between Indigenous people from Northern Territory (NT) and all Australians.

![Figure 2.1-1](image)

*Figure 2.1-1. Gap in life expectancy between Indigenous and non-Indigenous Australians (Australian Parliament House website, 2009)*

Poverty is a contributing factor to the reduced level of health experienced by Indigenous Australians, with many living in socio-economically disadvantaged areas (Durkin, 2008; Kelaher, Ferdinand, Ngo, Tambuwla, & Taylor, 2010). Other factors include poor health in early childhood, inadequate access to hygiene services, food, running water, transport and housing, and higher levels of unemployment (Durkin, 2008; King & Baxter, 2003).

Many Indigenous Australians also live in remote or very remote communities. The geographical isolation of these communities provides a significant disadvantage in terms of the availability of consistent primary health care services, as provision of care by health professionals to these remote areas can be time-consuming and not cost effective. In addition, Indigenous populations can be highly mobile (Kain et al.,
2007; Wright et al., 2009), making health reviews and ongoing improvement in health care challenging to facilitate. Cultural differences may also affect the willingness of Indigenous people to seek health care with some Indigenous Australians being reluctant to attend mainstream services such as hospitals and community health centres (Layland, Holden, Evans, & Bailey, 2004).

Australian Indigenous children also experience poorer levels of health. In addition to the factors affecting the Indigenous population more broadly, Indigenous children experience more forced separation or relocation from parents/grandparents as well as major life stressors such as family deaths, parental separation and divorce than non-Indigenous children. All of these factors have been suggested to collectively contribute to the higher number of health problems experienced by Indigenous children (Blair, Zubrick, Cox, & WAACHS Steering Committee, 2005).

Thirty six per cent of the Indigenous population is under 15 years of age compared with 19% of the general Australian population, see Figure 2.1-2. With over one third of the Australian Indigenous population being children, targeting this age group’s health has the potential to impact positively on the long-term health of Australian Indigenous people (Fremantle, Zurynski, Mahajan, D'Antoine, & Elliott, 2008).

*Figure 2.1-2. Australia’s population distribution by age group and Indigenous status (Australian Government, 2010)*
2.2 LITERACY AND NUMERACY SKILLS OF AUSTRALIAN INDIGENOUS CHILDREN

Educational outcomes of Indigenous children are also poorer than their non-Indigenous peers (Australian Curriculum Assessment and Reporting Authority, 2011; Australian Medical Association, 2001; Collins, 1999). The gap in reading and numeracy skills is apparent from a young age, and also increases as the child reaches Year 7 for numeracy skills (Australian Curriculum Assessment and Reporting Authority, 2011). This is demonstrated in Table 2.2-1 which shows the percentage of Year 3 and Year 7 Indigenous and non-Indigenous children at or above the minimum national standard in reading and numeracy skills in 2011.

Table 2.2-1
Queensland 2011 NAPLAN results: percentage of children reaching the minimum national standard in reading and numeracy (Australian Curriculum Assessment and Reporting Authority, 2011)

<table>
<thead>
<tr>
<th></th>
<th>Reading</th>
<th>Numeracy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Indigenous</td>
<td>Non-Indigenous</td>
</tr>
<tr>
<td>Year 3</td>
<td>76.3</td>
<td>94.9</td>
</tr>
<tr>
<td>Year 7</td>
<td>77.1</td>
<td>95.7</td>
</tr>
</tbody>
</table>

The Collins report was a landmark review of Indigenous education in the Northern Territory and evaluated the reduced educational outcomes of Indigenous children from primary school through to Year 12. Low reading and numeracy rates were attributed to a range of issues, the main one being poor school attendance. However, health issues such as nutritional deficits, hearing impairments, poor eyesight, anaemia and skin diseases were also considered to hinder effective learning, as they potentially reduce attendance, participation and the ability to learn (Collins, 1999). A total of 151 recommendations were made in the Collins report that addressed many aspects of Indigenous education, including student assessment, funding and costs, staff recruitment and retention and students with special needs and health issues. Despite these recommendations, in the seven years following the Collins report, no improvement was evident in the percentage of Indigenous children
reaching the minimum national standard for reading, writing and numeracy (Australian Bureau of Statistics, 2010), see Table 2.2-2.

Table 2.2-2
*Percentage of Year 7 Indigenous children reaching the minimum national standard (Ministerial Council on Education Employment Training and Other Youth Affairs, 2007)*

<table>
<thead>
<tr>
<th>Year</th>
<th>Reading (%)</th>
<th>Writing (%)</th>
<th>Numeracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>60.1</td>
<td>74.3</td>
<td>48.6</td>
</tr>
<tr>
<td>2002</td>
<td>65.3</td>
<td>71.6</td>
<td>51.9</td>
</tr>
<tr>
<td>2003</td>
<td>66.5</td>
<td>74.4</td>
<td>49.3</td>
</tr>
<tr>
<td>2004</td>
<td>71.0</td>
<td>78.8</td>
<td>51.9</td>
</tr>
<tr>
<td>2005</td>
<td>63.8</td>
<td>72.3</td>
<td>48.8</td>
</tr>
<tr>
<td>2006</td>
<td>63.2</td>
<td>73.8</td>
<td>47.5</td>
</tr>
<tr>
<td>2007</td>
<td>64.7</td>
<td>74.5</td>
<td>46.0</td>
</tr>
</tbody>
</table>

Reducing the disparity in reading, writing and numeracy between Indigenous and non-Indigenous children was one of the targets commissioned by the Council of Australian Governments (COAG), after the release of the 2009 Overcoming Indigenous Disadvantage Report (Australian Bureau of Statistics, 2010). The target was to halve the gap in reading, writing and numeracy outcomes between Indigenous and non-Indigenous children within a decade (Ministerial Council on Education Employment Training and Other Youth Affairs, 2012). This objective was set in 2008. In the seven years prior to 2008, the percentage of Indigenous children at or above the minimum national standard for reading, writing and numeracy had remained unchanged, see Table 2.2-2 (Australian Bureau of Statistics, 2010).

In 2008, NAPLAN tests (National Assessment Program – Literacy and Numeracy) were developed by the Australian Curriculum, Assessment and Reporting Authority, the States and Territories, non-government education sectors and the Australian Government (Australian Curriculum Assessment and Reporting Authority, 2011). Prior to the introduction of the Australia-wide NAPLAN test, each State and Territory undertook its own testing (Ministerial Council on Education
Employment Training and Other Youth Affairs, 2007). NAPLAN testing is now conducted annually, with over one million Years 3, 5, 7 and 9 children sitting the tests across Australia. A comparison of yearly NAPLAN results (National Assessment Program – Literacy and Numeracy) for reading and numeracy for the years 2008 – 2011 between Indigenous and non-Indigenous children showed that Indigenous children still consistently scored lower across all year levels, see Table 2.2-3 (Australian Curriculum Assessment and Reporting Authority, 2011). Although Indigenous children’s results were higher with the new testing system than for that represented in Table 2.2-2, the gap between Indigenous and non-Indigenous children’s outcomes is still evident. However, a positive sign is that Year 7 Indigenous children’s reading outcomes improved over this four year period (measured with the same test), suggesting that the gap between Indigenous and non-Indigenous children may be reducing in some areas.

Table 2.2-3
Percentage of Year 7 Indigenous and non-Indigenous children meeting the minimum national standard in reading and writing, 2008 – 2011 (Australian Curriculum Assessment and Reporting Authority, 2011)

<table>
<thead>
<tr>
<th></th>
<th>Reading</th>
<th></th>
<th>Numeracy</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Indigenous</td>
<td>Non-Indigenous</td>
<td>Indigenous</td>
<td>Non-Indigenous</td>
</tr>
<tr>
<td>2008</td>
<td>71.9</td>
<td>95.4</td>
<td>78.6</td>
<td>96.4</td>
</tr>
<tr>
<td>2009</td>
<td>73.2</td>
<td>95.0</td>
<td>75.8</td>
<td>95.8</td>
</tr>
<tr>
<td>2010</td>
<td>76.6</td>
<td>95.9</td>
<td>77.0</td>
<td>96.1</td>
</tr>
<tr>
<td>2011</td>
<td>77.1</td>
<td>95.7</td>
<td>76.5</td>
<td>95.5</td>
</tr>
</tbody>
</table>
2.3 VISION CONDITIONS AND THEIR ASSOCIATION WITH READING ABILITY

A number of vision conditions (uncorrected hyperopia, accommodation and/or vergence disorders and delayed visual information processing [VIP] skills) have been associated with reduced educational performance in the wider population (Krumholtz, 2000; Kulp, 1999; Rosner & Rosner, 1997; Shin et al., 2009; Williams et al., 2005). However, the extent to which visual dysfunction impacts upon educational achievement has been the focus of longstanding debate amongst health and education professionals (Eames, 1959; Helveston et al., 1985; Simons & Grisham, 1986).

To date, there have been many correlational studies demonstrating that an association exists between reduced vision and reduced academic achievement (Chen et al., 2011; Krumholtz, 2000; O'Grady, 1984; Rosner & Rosner, 1997; Williams et al., 2005). There have also been numerous flaws between studies which reduce the confidence that can be placed on many of the findings (Bonilla-Warford, 2004). These include poor methodology (subjective teacher judgments used instead of standardised tests to determine reading or academic ability), small sample sizes, incorrect statistical analysis, poor selection of comparison groups, experimenter bias, lack of masking, inconsistencies with definitions of terms used for reading ability and academic ability, and different measurement techniques. Furthermore, many other non-visual factors are likely to contribute to a child’s academic performance including low birth-weight, hearing impairments, decreased school attendance and socio-economic and ethnic background (Dirani, Zhang, et al., 2010; Gonski et al., 2011; Kattouf & Steele, 2000; Ozmert et al., 2005).

Reading disability and language impairment also often co-exist, with research suggesting that reading skill development is primarily based on auditory-verbal language skills (Vellutino, Fletcher, Snowling, & Scanlon, 2004). A large body of work has shown that many children with reading disability have a deficit in phonological coding which is related to poor phonological awareness (Pennington & Bishop, 2009; Vellutino et al., 2004), with this measure being the strongest single correlate of reading ability (Shankweiler et al., 1995).

A deficit in rapid automatised naming (RAN) has also been identified as a risk factor for reading disability. The double deficit hypothesis proposes that a
phonological deficit and RAN deficit may co-exist and are subsequently both associated with reading disability (Wolf, Bowers, & Biddle, 2000). Understanding the contribution of phonological and RAN deficits to reading disability, as well as the other factors listed above, may help to explain a substantial percentage of reading disability. However, it should be noted that RAN does require visual input so it is possible that visual ability may also be a contributing factor to this model.

A lack of understanding of the role that age plays on some visual measures and academic ability is also a recurring flaw in the literature. The level of association of given visual parameters with academic ability varies dependent on the age. The ‘learning to read’ stage covers a younger age group of school children than the ‘reading to learn’ stage and both tasks present different visual demands on the child. In the ‘learning to read’ stage, the emphasis is on acquiring the ability to interpret a new print-based language code; the print is large, spaced more widely and has shorter words in this early phase. Reading is slow and the amount of reading material needing to be processed is minimal (Borsting & Rouse, 1994; Dearborn, 1945; Pierce, 1977). In the later ‘reading to learn’ stage, it is assumed that children have the requisite skills and are now engaging in reading in order to access information. Children are required to sustain high levels of attention for longer periods and learning tasks may involve rapid and repeated changes in accommodation (Kulp & Schmidt, 1996). The visual demands are therefore different between the two stages. ‘Learning to read’ demands adequate ocular motor control, visual form perception and visual memory, that is, visual information processing skills. ‘Reading to learn’ requires adequate ocular motor control, comfortable binocular vision and accommodative control, such that a higher demand is placed on binocular vision (Bonilla-Warford, 2004; Kedzia, Tondel, Pieczyrak, & Maples, 1999; Leslie, 2004). Meares-Irlen Syndrome/Visual Stress (MISViS) also becomes more problematic during this stage, as the text becomes smaller and more crowded (Allen, Evans, & Wilkins, 2012). However, as MISViS is not a vision condition tested in any children’s vision screenings, it was considered outside the scope of this thesis.

Some authors have failed to find an association between binocular vision function and academic ability in young children who are at the ‘learning to read’ stage (Kedzia et al., 1999), whilst other authors have failed to find any association
between VIP skills and academic ability in older children who are in the ‘reading to learn’ stage (Goldstand et al., 2005), thereby ignoring the skills that are theoretically most critical at each of these specific stages of learning. In addition to poor research design, inconsistencies in the terminology and definitions used for reduced reading or academic ability is also a problem in this area of research.

2.3.1 DEFINITIONS OF READING AND LEARNING DISABILITY

Reading and other learning disabilities are often not well defined in the literature. Reading disabilities can range from mild reading inefficiencies, to moderate and severe reading disabilities (Leslie, 2004). The severity of a reading disability can be defined by the number of years that a child’s reading age is behind their chronological age (Bonilla-Warford, 2004). Reading disabilities can be further classified as either specific or non-specific. Dyslexia is a specific reading disability, whereas non-specific reading disabilities may exist in the presence of one or more of the following factors: low intelligence, developmental delay, educational and/or socio-cultural deprivation, emotional problems and/or sensory impairments, such as vision impairment. Therefore, the diagnosis and management of reading disabilities requires consideration of many different factors. Children identified as having a reading disability require multi-disciplinary interventions to address the potential educational, visual, medical, social and family and psychological factors of the disability (Zaba, 2001).

Another methodological challenge that is frequently found in the literature investigating vision and academic ability involves the definition of vision impairment in relation to its effect on academic ability. Many researchers have investigated the effect of a single visual measure such as refractive error, ocular motor function or visual acuity on academic ability (Suchoff, 1981). This has been criticised as being too simplistic (Grisham & Simons, 1986) and it has been recommended that researchers avoid focusing on just one particular aspect of visual function when considering the relationships of vision and academic ability (Kedzia et al., 1999). An alternative approach is to evaluate the effect of a range of measures of visual function (e.g. visual acuity and refraction, visual efficiency and visual information processing) and determine how they are associated with each other and measures of academic ability.
2.3.2 HISTORICAL BACKGROUND

As early as the 1930s, the impact of reduced vision on academic ability was investigated. Eames, a physician, and Betts, a psychologist, shared strong interests in the field and evaluated the interaction of different visual factors with learning, as well as the effect of other physical factors on learning, such as birth weight, speech difficulties, and physical handicaps (Betts, 1934; Eames, 1935).

Eames’ research compared ‘reading disability’ groups with ‘unselected’ groups and evaluated the prevalence of different vision impairments between these groups (Eames, 1932, 1934a, 1934b, 1935, 1944, 1948, 1949, 1955, 1959, 1964). The main findings from Eames’ studies were:

- Hyperopia of one dioptre or more is present in 43% of children with reading disability compared with 13% in an unselected group;
- Convergent strabismus occurred twice as often in children with reading disability;
- Those with reading disability had more exophoria (>6 prism dioptres) at near.

Reduced positive fusional vergence, amblyopia and anisometropia were also positively correlated with reduced reading ability in Eames’ studies. Eames’ work, however, has been criticised for poor study design and inappropriate choice of control groups; the use of an ‘unselected’ control group relies on the assumption that the group is comprised of normal readers, however, poor readers may also have been allocated to this group (Simons & Grisham, 1986). In addition, reading disability was not clearly defined. Different reading tests have been used between studies to define reading disability, and in some cases standard reading tests were not used, and instead, reports based on school marks or the general impression of the respective teachers were used to classify reading disability (Eames, 1934a).

In 1934, Betts developed the Telebinocular Vision Screening test and assessed kindergarten children’s visual acuity, refractive error, vertical and horizontal heterophorias, distance and near fusional reserves and stereopsis. Unlike Eames’ findings, no association was found between reduced vision, measured with the Telebinocular Vision Screening test, and reduced academic ability (Dalton, 1943; Spache & Tillman, 1962; Stromberg, 1938; Swanson & Tiffin, 1936; Witty, 1936).
This finding however, raises the question as to whether Betts’ Telebinocular Vision Screening test was an accurate measure of visual ability.

2.3.3 VISUAL ACUITY

The general consensus in the literature is that habitual distance visual acuity is unrelated to academic ability (Dirani, Zhang, et al., 2010; Evans, 1998; Evans, Drasdo, & Richards, 1992b, 1994b; Flax, 1970b, 1973; Grisham, Powers, & Riles, 2007; Grisham & Simons, 1986; Spierer & Desatnik, 1998). In a large sample of Year 4 Singaporean children, the level of habitual visual acuity did not have a significant effect on academic ability, where academic ability was determined by the nationwide Year 4 examinations of language and mathematics proficiency (Dirani, Zhang, et al., 2010). Similarly, Grisham et al. (2007) failed to find a significant association between reduced visual acuity and poor reading in a sample of high school students. Many other studies have also failed to find any significant relationship between distance visual acuity and academic ability (Bedwell, Grant, & McKeown, 1980; Blika, 1982; Chernick, 1978; Helveston et al., 1985; Shearer, 1966). One possible explanation for these findings is that the visual acuity demands required for most school tasks do not require spatial resolution to be as detailed as 6/6.

There has been one study that has quantified the visual acuity demands required in a classroom. In this study, the visual acuity demands for primary school children sitting in the back row of a classroom ranged from 6/15 – 6/60, based on measurements from six classrooms in one primary school (Langford & Hug, 2010). In a different study conducted in eleven classrooms from four different schools, the average distance from a student’s desk to the chalkboard and the average classroom lighting levels were measured (Ritty, Solan, & Cool, 1993). However, as the size of the text on the chalkboard was not recorded, visual acuity demands could not be calculated.

Only two studies have shown an association between reduced distance visual acuity and academic ability. The first study reported that a habitual distance visual acuity of worse than 6/8 was significantly related to a reduction in overall educational performance in Year 2 Tasmanian children (O'Grady, 1984). In a separate study performed on Year 2 Malaysian school children, a significant association was found between children with reduced visual acuity (<6/12) and
reduced academic ability - based on school examination results at the end of Year 1 (Chen et al., 2011). In the case of these two studies, it may be that a large proportion of the classroom teaching takes place on the board, requiring better distance acuity; however, the results of Langford’s study in which the visual acuity demand is only 6/15 or worse (back row of classroom) do not provide support for this explanation.

2.3.4 REFRACTIVE ERROR

Hyperopia

Many studies have reported a positive association between uncorrected hyperopia and reduced academic ability (Bonilla-Warford, 2004; Borsting & Rouse, 1994; Christenson, Griffin, & Wesson, 1990; Garzia & Nicholson, 1990; Grisham & Simons, 1986; Maples, 2003; Palomo-Alvarez & Puell, 2009; Rosner, 2004; Simons, 1993; Simons & Gassler, 1988; Spierer & Desatnik, 1998). Only one study was found that showed no association between hyperopia and reading performance (Evans et al., 1992b), however, this study investigated the link between hyperopia and reading in terms of dyslexia, a condition that is beyond the scope of this thesis. What is less clear is what level of uncorrected hyperopia affects academic ability, as the definition used for hyperopia ranges between studies from any power greater than plano to greater than three dioptres of hyperopia. Four separate studies have shown that uncorrected hyperopia of more than 1.25 dioptres was related to reduced academic performance (Godts et al., 1999; Krumholtz, 2000; Rosner & Rosner, 1997; Williams et al., 2005). However, other levels of hyperopia including greater or equal to two dioptres (Shankar et al., 2007), greater or equal to 0.75 dioptres (Fulk & Goss, 2001) and greater than 0.75 dioptres (Rosner & Rosner, 1987) have also been related to decreased academic achievement. A recent review article concluded that a number of studies have suggested that school children with moderate levels of uncorrected hyperopia may experience reading or academic problems. However, randomised controlled clinical trials are still required to validate appropriate prescribing strategies for hyperopic children with reading or academic difficulties (Cotter, 2007).

Myopia

Unlike hyperopia, myopia has been associated with average or above average reading levels (Simons & Gassler, 1988) and is associated with high levels of academic performance (Mutti, Mitchell, Moeschberger, Jones, & Zadnik, 2002;
Young et al., 1970). In the Singapore Cohort Study of the Risk Factors for Myopia (SCORM study), nonverbal IQ (controlling for reading) was associated with myopia and axial length; subsequently, children with a higher IQ were more likely to be myopic (Saw et al., 2007).

In the UK, the Avon Longitudinal Study of Parents and Children (ALSPAC) reported a positive correlation between verbal IQ testing and myopia, but did not show any association between non-verbal IQ and myopia (Williams, Miller, Gazzard, & Saw, 2008). The ALSPAC study concluded that the differences between their findings and those of the SCORM study may be due to differences in the IQ tests used (verbal or non-verbal), or differences in populations – that is, Singaporean students may spend longer amounts of time performing near tasks compared to UK children. These conclusions suggest that there may be other components affecting the relationship between myopia and academic ability, such as time spent outdoors, which is believed to be a protective factor for myopia (He, Zheng, & Xiang, 2009; Jones-Jordan et al., 2011; Rose, Morgan, Ip, et al., 2008).

None of the studies that found an association between myopia and higher academic ability reported whether the children wore spectacles or contact lenses for their myopia, and whether this correction was the correct prescription. Only one study looked at the effect of uncorrected myopia on academic ability (Ozmert et al., 2005). In this study of Year 1 children from Turkey, uncorrected myopia was associated with reduced academic ability, as determined by the child’s teacher. A limitation of this study, however, was that academic ability was determined by teacher report and not by a standardised test.

**Astigmatism**

The Navajo population (American Indian) have been reported to have a high prevalence of astigmatism compared to the wider American population (Garber, 1981). The impact of this uncorrected high corneal astigmatism in Navajo children on school performance was also investigated. Over one quarter of the children in the study had corneal astigmatism of at least two dioptres, with close to half a grade difference in classroom grades between children with uncorrected high astigmatism and no astigmatism and visual acuity of 6/9 or better, with the children with astigmatism scoring lower. The author highlighted the importance of adequate screening for astigmatism in this population, as 32 per cent of children had high
corneal astigmatism but had a visual acuity of 6/9 or better and thus passed the visual acuity screening criteria. Additional screening tests for refractive error are required in this group given the high levels of uncorrected astigmatism and the negative impact it has on their classroom grades.

In another study, induced astigmatism resulted in reduced reading performance in young adults (Wills et al., 2012). The reading speed for large print (N16) was reduced by 10% with two dioptres of astigmatism, and for smaller print sizes, reading speed was reduced by up to 24% with one dioptre of astigmatism. Importantly, the axis of astigmatism affected reading speed differently, with against the rule astigmatism having a greater effect on performance than with the rule astigmatism (Wills et al., 2012).

**Anisometropia**

The only study that has investigated the association between anisometropia and academic ability was conducted in 1948. In this study, Eames (1948) found that 13% of children in a ‘reading failure’ group had anisometropia compared with 6% of children in an ‘unselected group’. However, the validity of many of Eames’ studies has been questioned (section 2.3.2); furthermore, the definition used for anisometropia was not reported.

### 2.3.5 ACCOMMODATIVE AND VERGENCE FUNCTION

Two different approaches have been used by researchers to determine whether there is an association between accommodative and/or vergence disorders and academic ability. The first approach investigates the academic ability of participants with accommodative and/or vergence disorders, such as accommodative insufficiency or convergence insufficiency (Abdi, Brautaset, Rydberg, & Pansell, 2007; Rouse et al., 2009); while the second approach examines the relationship between a single measure of accommodation or vergence (such as accommodative facility or near point of convergence) and academic ability. The second approach, albeit the more commonly used, does not interpret the accommodative-vergence function as an overall system (Simons & Grisham, 1986). For example, a large phoria does not necessarily correspond to a vergence disorder, as other compensatory mechanisms such as a high positive fusional vergence may negate its effect.
The effect of the following accommodation and vergence measures on academic ability has been investigated: heterophoria, vergence range, near point of convergence, vergence facility, amplitude of accommodation, negative and positive relative accommodation, accommodative facility and MEM retinoscopy (Evans, Drasdo, & Richards, 1992a; Goldstand et al., 2005; Kulp & Schmidt, 1996; Morad et al., 2002; Palomo-Alvarez & Puell, 2008, 2009; Shin et al., 2009; Stavis et al., 2002; Vaughn, Maples, & Hoenes, 2006). Results vary, and while many studies have found a positive association between academic ability and individual measures of accommodation and vergence, many studies have not. Nevertheless, the following are common findings throughout the literature:

- High exophoria at near, vertical phoria and reduced positive fusional range at distance and near are all related to reduced academic ability (Atzmon, Nemet, Ishay, & Karni, 1993; Evans, 1999; Flax, 1970a; Grisham, Sheppard, & Tran, 1993; Grosvenor, 1977; Lightstone & Evans, 1995; Simons & Grisham, 1987).

- Accommodative and/or vergence disorders have a greater impact on children who are ‘reading to learn’, that is are in the later stages of primary school, compared with children who are ‘learning to read’ in the earlier years of schooling (Borsting & Rouse, 1994; Flax, 1970b; Kedzia et al., 1999; Kielty, Crewther, & Crewther, 2001; Kulp & Schmidt, 1996). This is likely to arise because as children progress through primary school, print size decreases and children are expected to maintain focus for increased periods of time. Subsequently, changes in accommodation and vergence are required more frequently. One potential reason for the failure of some studies to find an association between accommodative and/or vergence disorders and academic ability, may be that the participants tested were too young. During the early stages of a child’s reading development, accommodation and vergence skills do not appear to play a major role in the child’s performance (Borsting & Rouse, 1994; Helveston et al., 1985; Kedzia et al., 1999; Letourneau, Lapierre, & Lamont, 1979; Ygge, Lennerstrand, Rydberg, Wijecoon, & Pettersson, 1993).

- Disorders of accommodation and accommodative-vergence are more frequently related to academic ability than vergence disorders alone. Shin
et al. (2009) found a significant reduction in academic scores, measured by nationwide testing, in children with accommodative and accommodativevergence disorders. However, academic scores in children with only a vergence disorder did not differ significantly from those of the control group. This finding is supported in other studies where no relationship was found between near point of convergence and/or other vergence measures and academic ability (Blika, 1982; Helveston et al., 1985; Letourneau et al., 1979; Morad et al., 2002). Many of these latter studies however have been criticised for inappropriate subject selection (that is, children in younger age groups were tested, where accommodative vergence disorders are not as critical), lack of adequate control group, selection criteria used for visual anomalies, and not ruling out suppression which questions the application of their findings (Simons & Grisham, 1987).

The Convergence Insufficiency Treatment Trial (CITT) study group has recently shown in a randomised clinical trial that treatment of convergence insufficiency (CI) resulted in an improvement in Academic Behaviour Survey scores (as graded by the child’s parent) twelve weeks after the beginning of a treatment program (Borsting et al., 2012). The Academic Behaviour Survey (ABS) is a 6-item survey designed by the CITT study group to quantify the number of adverse school behaviours as well as parental concerns about school performance. This was the first study that has reported the impact of treating CI on academic behaviours as reported by parents.

2.3.6 AMBLYOPIA

A number of studies have investigated academic ability and/or reading speed of children with amblyopia (Kulp & Schmidt, 1997; Latvala, Korhonen, Penttinen, & Laippala, 1994; Stifter, Burggasser, Hirrmann, Thaler, & Radner, 2005a, 2005b). Binocular maximum reading speed was used as a measure of reading ability in one study and, despite binocular visual acuities being equal between the amblyopic and control groups, binocular maximum reading speed was found to be reduced in the amblyopic group (Stifter et al., 2005a, 2005b). The adequacy of binocular maximum reading speed as an accurate measure of reading ability was questioned in a second study, which used a non-verbal test of IQ (Koklanis, Georgievski, Brassington, &
Bretherton, 2006). The prevalence of reading disability in the amblyopic group in this study was measured using the Wide-Range Achievement Test (a non-verbal IQ test) and tests of phonological processing and rapid automatised naming (RAN). Findings from the study demonstrated that lower IQ scores were not associated with amblyopia, however, reduced RAN scores had an association with amblyopia which is consistent with other studies which also reported reduced binocular reading speed in amblyopes (Stifter et al., 2005a, 2005b).

2.3.7 STRABISMUS

While a number of studies have investigated the effect of strabismus on academic ability (Atzmon et al., 1993; Blika, 1982; Cassin, 1976; Reed, Kraft, & Buncic, 2004; Ygge et al., 1993), only one reported a positive correlation between strabismus and reduced academic performance (Reed et al., 2004). However, one important limitation of this study was that academic achievement was measured by parental reporting and not a standardised test.

The general consensus in the literature is that binocular inefficiencies such as decompensated phorias or accommodative vergence disorders are more likely to interfere with reading ability than a constant strabismus (Flax, 1970b; Simons & Grisham, 1987; Spierer & Desatnik, 1998). In fact, a higher prevalence of reading disorders was found in children who had undergone strabismus surgery and were achieving varying levels of fusion compared to children with constant strabismus and no fusion (Simons & Grisham, 1987).

2.3.8 STEREOPSIS

A number of studies have investigated the association between stereoacuity and academic ability, with varying conclusions. A significant correlation has been shown between reduced stereoacuity (stereoacuity greater than 100 seconds of arc) and academic ability (Kulp & Schmidt, 2002). In their study, stereoacuity was selected because it can result from a number of different vision conditions, such as reduced binocular/monocular visual acuity, significant refractive error and/or binocular vision abnormalities. In a separate study, reduced stereopsis (greater than 50 seconds of arc) in conjunction with failure of the Modified Clinical Technique (a battery of tests commonly used in vision screenings) was found to also be a good predictor of reduced academic ability (Kulp & Schmidt, 1996).
The prevalence of reduced stereoacuity (greater than 100 seconds of arc) was also found to be higher in children with low literacy levels (below the 10th percentile) compared to the wider population (Ponsonby et al., 2013). In their study, one in six children with low literacy had reduced stereoacuity.

However, another study failed to find a difference in mean stereoacuity scores between children with reading disability and normal readers (Palomo-Alvarez & Puell, 2009). Differences in statistical analyses between the studies may have resulted in the different outcomes. In the latter study, the mean stereoacuity between two groups was compared using ANOVA. Considering that stereoacuity approximates a logarithmic distribution this statistical approach may not have been ideal. The studies that did find an association between stereoacuity and reading outcomes, treated stereoacuity as a categorical variable, and classified participants as having either normal or reduced stereoacuity.

### 2.3.9 Visual Information Processing Skills and Academic Ability

A model commonly used to classify visual information processing (VIP) skills is to group VIP skills into the following three areas – visual spatial, visual analysis and visual motor skills (Borsting & Rouse, 1994). Visual spatial skills relate to the concept of directionality; visual analysis skills relate to the recognition, recall and manipulation of visual information, while visual motor skills rely on the coordination of visual information processing skills with fine motor skills.

Many authors have reported a positive association between delayed VIP skills and reduced academic or reading ability using one or more the following tests: Test of Visual Analysis Skills (TVAS), Reversals Frequency Test (RFT), Motor-Free Visual Perception Test (MVPT), Beery’s Visual Motor Integration test (VMI) and the Test of Visual Perceptual Skills (TVPS) (Kattouf & Steele, 2000; Kavale, 1982; Kulp & Schmidt, 1996; Maples, 2003; Woodrome & Johnson, 2009). These tests measure a range of VIP skills, and the relevance of the test results depends on the age group tested. The TVAS, TVPS, VMI and RFT all assess VIP skills useful for the learning to read stage, that is, until Year 3, (Chall & Jacobs, 1983), where the task of reading involves the decoding of print, and the recognition, matching and recall of shapes, and understanding of the direction and orientation of letters is important. A number of studies have reported that VMI in particular is a useful predictor of academic ability when tested with Beery’s VMI test (Daniels & Wong, 1993; Kulp,
Visual sequential memory which is measured by a sub-test of the TVPS may also be relevant for the reading to learn stage (Year 3 onwards) where the task can involve longer passages of text, and adequate visual sequential memory in particular is required.

There are also studies that have found no association between VIP skills and academic ability (Goldstand et al., 2005; Shankar et al., 2007; Shovman & Ahissar, 2006). Potential reasons for these findings are that many of the children in the studies were beyond the ‘learning to read’ stage (VIP skills are thought to be more important in younger children) and small sample sizes were used, which can be less reliable, making it more difficult to identify significant effects (Pierce, 1977; Simons & Grisham, 1986); or, it may simply be that no association exists between VIP skills and educational ability. In summary, the volume of literature investigating the effect of VIP skills on academic ability is far less extensive than that of visual acuity, refractive error and binocular vision function. Nevertheless, many different authors have indicated that an association between VIP skills, in particular VMI, and academic ability exists (Daniels & Wong, 1993; Kulp, 1999; Maples, 2003; Sherman, 1973).

2.3.10 SUMMARY

Certain vision conditions may be a risk factor for reduced academic ability. However there are many other factors that are also related to reduced academic ability (for example, delayed auditory-verbal language skill development, socio-economic status, hearing impairments, low school attendance), and these factors either in isolation or in combination with visual and/or other factors can have a detrimental effect on academic performance in some children. All of these factors, including vision, require consideration in the assessment and/or management of children at risk of poor academic performance. A comprehensive visual assessment is an important component of a multi-disciplinary approach required for these children.

Despite the variable nature of the findings in the vision and reading/academic ability-related research, the following conclusions recur frequently in the literature:

- Uncorrected hyperopia is associated with reduced academic ability in both younger and older school children;
Some VIP skills are associated with academic performance in younger school children who are “learning to read”;

Accommodation and vergence function is more important in older school children who have entered the “reading to learn” phase;

There has been a notable lack of research investigating these three factors, as well as other vision and ocular health conditions in Australian Indigenous children. With the known gap in reading ability between Indigenous and non-Indigenous children, investigation of the prevalence of these vision conditions that have been linked with reduced reading ability is required.

2.4 VISION CONDITIONS IN AUSTRALIAN INDIGENOUS CHILDREN

2.4.1 VISION IMPAIRMENT

Only two studies were identified that have reported the prevalence of reduced visual acuity in Australian Indigenous children. The National Indigenous Eye Health Survey (NIEHS) was a large study conducted in 2009 across Australia. The aim of the NIEHS was to define the extent, cause and impact of vision loss in Australian Indigenous people. A total of 1694 Indigenous children (aged between 5 – 15 years) and 1189 Indigenous adults (aged 40 years and over) were examined.

The NIEHS defined reduced visual acuity (vision impairment) as a habitual bilateral visual acuity of worse than 6/12. One and a half percent of Indigenous children had vision impairment, with the authors concluding that Indigenous children were five times less likely to have vision loss than non-Indigenous children, based on the prevalence of vision impairment reported for Australian non-Indigenous children in other studies (Taylor et al., 2009). These findings suggest that the prevalence of conditions that cause reduced visual acuity (e.g. uncorrected or under-corrected refractive error and amblyopia) is lower in Australian Indigenous children. In the NIEHS, uncorrected refractive error was responsible for 54% of vision impairment in Indigenous children (Taylor et al., 2009), compared with 67% of vision impairment in non-Indigenous children reported in a separate study (Robaei, Rose, Kifley, & Mitchell, 2005). Other causes of visual acuity loss in this study were amblyopia, congenital nystagmus and retinal disorders.

Blindness was defined as a habitual bilateral visual acuity of worse than 6/60 in the NIEHS. The prevalence of blindness in Indigenous children was 0.18%, which is
lower than the 0.28% reported in children in the wider Australian population; the relative risk of bilateral blindness is 0.6 times in Indigenous children, compared with non-Indigenous children (Taylor et al., 2009). Indigenous children also experienced less bilateral blindness than Australian Indigenous adults; 1.9% of Indigenous adults tested in the NIEHS were classified as blind, which was 6.2 times that found in the wider Australian population (Taylor, Xie, et al., 2010). The main causes of vision loss in Indigenous adults were uncorrected refractive error, cataract, diabetic retinopathy and trachoma. Of these conditions, uncorrected refractive error is the only condition that is also visually-disabling in children. Although trachoma predominantly affects children, and is prevalent in remote Aboriginal communities (Taylor et al., 2009), the vision impairment caused by trachoma manifests later in life. These reasons are likely to explain why blindness rates are higher in Indigenous adults compared with Indigenous children.

A second study also measured the prevalence of vision impairment (<6/18) and blindness (<6/120) in Australian Indigenous children (Stocks, Hiller, & Newland, 1997). However, unlike the NIEHS, the definition used for blindness was the same as that used by the World Health Organisation, that is, less than 6/120. No vision impairment was found in 455 Indigenous children aged between 0 and 19 years from seven communities in South Australia. In fact, all of the children except one had 6/6 or better vision in both eyes.

The prevalence of severe vision impairment and blindness in childhood has been shown to be higher in populations that are socio-economically disadvantaged and/or have higher mortality rates amongst children under the age of 5 years (Gilbert & Foster, 2001). In Australia, the under-5 mortality rate for Indigenous children (2.3 per 1000) is more than double the under-5 mortality rate of non-Indigenous children (1.1 per 1000), (Department of Indigenous Affairs, 2010). The Indigenous population is also more disadvantaged in terms of education, income and employment outcomes compared with the wider Australian population (Australian Human Rights Commission, 2005). Nevertheless based on reduced visual acuity findings alone, vision impairment is less prevalent compared with non-Indigenous children, despite Indigenous children having significantly more other physical and mental health problems (Blair et al., 2005).
2.4.2 REFRACTIVE ERROR

The NIEHS is the only study that has reported the prevalence of refractive error in Australian Indigenous children. In the NIEHS, refractive error was only measured with autorefration in children whose unaided visual acuity was less than 6/12 and it improved with a pinhole. This method of selectively measuring refractive error, however, has its limitations as low to moderate levels of hyperopia, and some types of astigmatism may not be detected, as they do not reduce visual acuity to less than 6/12.

The overall prevalence of refractive error measured in Indigenous children was 8.7% in the NIEHS. The breakdown of hyperopic, myopic and astigmatic refractive errors was not reported. Of the children with refractive error, only 8% had spectacles. Furthermore, of the children who were wearing spectacles, over one quarter were not wearing the correct lens power, which was responsible for the reduced visual acuity of <6/12 (Taylor, Xie, et al., 2010). It is possible that more children were wearing the incorrect prescription, but were not identified in that study if their visual acuity was 6/12 or better (Taylor, Xie, et al., 2010).

2.4.3 ACCOMMODATION AND/OR VERGENCE DISORDERS, STRABISMUS AND AMBLYOPIA

Only one study has measured the prevalence of strabismus in Indigenous children. In this study, the results from school screenings performed in the Top End, NT were used to determine the prevalence of strabismus with less than one percent of Indigenous children reported as having strabismus (Paterson, Ruben, & Nossar, 1998). However, the technique used to detect strabismus and the type of strabismus was not reported.

Other studies have reported the prevalence of strabismus and/or amblyopia as very rare in the Australian Indigenous population. One study found no cases of convergent strabismus amongst 804 Aboriginal people examined in the Western Desert Region (Mann & Rountree, 1968). While in the National Trachoma and Eye Health Project (NTEHP) the prevalence of esotropia was 0.2% in Aboriginal people (all ages) compared with 0.5% in the wider population, and the prevalence of exotropia (0.5%) was equal to that found in the wider population (Thomson & Paterson, 1998). Neither of these studies reported the results specifically for children; the findings presented were for children and adults combined.
Overall, there is limited information on the prevalence of strabismus and amblyopia in Indigenous children; two conditions that are routinely screened for in children generally. In addition, the prevalence of accommodation and/or vergence disorders has not been reported at all in Australian Indigenous children.

2.4.4 VISUAL INFORMATION PROCESSING SKILLS

Visual memory skills were evaluated in Aboriginal children in two studies from the 1970s. Kearins (1978) reported that visual spatial memory skills were more developed in Aboriginal children compared with non-Aboriginal children, while Drinkwater (1976) found no significant difference in visual memory skills between Aboriginal children and non-Aboriginal children. Both studies used a number of non-standardised memory tasks to measure visual spatial memory skills. The difference in the samples between the two studies (rural Aboriginal community and metropolitan Aboriginal community) may have resulted in the different findings, as the age of the participants and methodological approach were otherwise similar. No other studies have investigated visual information processing skills in Australian Indigenous children.

2.4.5 CONCLUSION

Overall, there is limited knowledge regarding Australian Indigenous children’s vision. The prevalence of refractive error, strabismus and amblyopia, despite being routinely screened for as part of a standard children’s vision assessment in the wider community, is not well documented in this population. Similarly, the prevalence of accommodation and/or vergence disorders and delayed visual information processing skills has not been documented, even though both of these conditions have been associated with reduced reading performance in children in the wider community (Atzmon et al., 1993; Evans, 1999; Flax, 1970a; Grisham et al., 1993; Grosvenor, 1977; Kattouf & Steele, 2000; Kulp & Schmidt, 1996; Lightstone & Evans, 1995; Shin et al., 2009; Simons & Grisham, 1987; Woodrome & Johnson, 2009). Understanding the prevalence and impact on reading of these conditions would assist in ensuring adequate resources are available for detecting and managing these conditions in Australian Indigenous children.
Vision screenings are one method of detecting potential vision conditions in children who may otherwise not present for an eye examination, be it due to limited access to existing services (as is common in many remote communities) or due to a limited uptake of existing services.

2.5 VISION SCREENINGS IN AUSTRALIA

2.5.1 BACKGROUND

The purpose of paediatric vision screenings is to detect children who have, or are at risk of developing, specific age-relevant vision problems. It is important to identify such vision problems in a timely manner as many can be managed effectively once identified. For a number of these conditions, for example, retinoblastoma or amblyopia, early detection reduces morbidity and facilitates successful treatment outcomes (Marshall, Meetz, & Harmon, 2010). Availability of valid and reliable test batteries is fundamental to successful detection and appropriate referral for treatment. There is ongoing debate, however, regarding the cost effectiveness of paediatric vision screenings, the exact tests that should be included in these screening batteries, and the ideal age for administration. The advantages of treating amblyopia (a condition frequently targeted in vision screenings) is also commonly debated, with some practitioners arguing that amblyopia treatment induces significant health anxiety and visual disability at a critical stage of the child’s development which leads to a poorer quality of life (Kulp et al., 2014).

Vision conditions that are predominantly screened for in childhood include amblyopia and its risk factors, refractive error, colour vision deficiency (CVD) and ocular pathology (for example, congenital glaucoma, congenital cataract or retinoblastoma), (Cummings, 1996; Ethan & Basch, 2008; Stewart-Brown & Haslum, 1988; Tengtrisorn, Sangsupawanitch, & Chansawang, 2009; Thomson & Evans, 1999). Colour vision assessment is, however, not always included in screening batteries on the basis that congenital CVD is untreatable and the role of CVD in the learning process has not yet been well established (Oberklaid, Wake, & Harris, 2002). Screening for accommodation and/or vergence disorders and hyperopia is better accepted, given that there is some evidence of an association between these conditions with impaired academic performance (Godts et al., 1999; Krumholtz, 2000; Reed et al., 2004; Rosner & Rosner, 1997; Stifter et al., 2005a).
In 2009 an Australian group, under the auspices of the National Children’s Vision Screening Project (NCVSP), undertook a systematic literature review of the effectiveness of vision screening programs (Morcos & Wright, 2009). The NCVSP subsequently established an expert Project Advisory Group (PAG), which recommended that vision assessment be undertaken at birth, between 3 and 6 months, and at four years of age (one year prior to school commencement). The NCVSP review concentrated only on vision screening programs that targeted reduced visual acuity, strabismus, congenital cataract and congenital glaucoma. However, other conditions such as uncorrected hyperopia and accommodation and/or vergence disorders have been shown to have an association with reduced academic ability (Godts et al., 1999; Krumholtz, 2000; Palomo-Alvarez & Puell, 2008). These vision conditions were not included in the NCVSP review, which constitutes a limitation of the NCVSP’s final recommendations, as it can be argued that not all vision conditions relevant to children were considered. Indeed, the optimal age group at which these conditions would be detectable via vision screening may be different from those recommended by the PAG.

Importantly, the NCVSP’s recommendation regarding the optimal age for children to be screened is not universally accepted. While screening at preschool may detect amblyopia earlier, screening in the first year of school provides a higher coverage because of compulsory school attendance, and represents a more time efficient way to screen all children within a geographical region (Hall & Stewart-Brown, 1998; Williamson, Andrews, & Dutton, 1995). The Pediatric Eye Disease Investigator Group have shown that for children aged seven years or less, the age at which amblyopia treatment is instigated does not affect the final outcome (Pediatric Eye Disease Investigator Group, 2002). A separate randomised controlled clinical trial also showed that delaying treatment until the age of five did not influence the effectiveness of the treatment (Clarke, Wright, Hrisos, Anderson, & Henderson, 2003). This suggests that the presumed age of treatment for amblyopia is not as critical as was previously believed.

2.5.2 DEVELOPMENT OF VISION SCREENING PROTOCOLS

The US-based Orinda study pioneered the systematic investigation of specific vision parameters that comprise an effective paediatric vision screening battery. This involved a three year study of primary school children from the Orinda School
District in California, which commenced in 1954. Reduced visual acuity, refractive error, binocular vision dysfunction and ocular pathology were identified as specific problems that should be prioritised for screening (Blum, Peters, Betman, Johnson, & Fellows Jr, 1959; Blum, Peters, Bettman, Fellows Jr, & Johnson, 1959). What has since become known as the Modified Clinical Technique (MCT), provided the highest sensitivity and highest specificity in terms of detecting the targeted vision conditions and was the first vision screening protocol to be validated. The MCT is often considered to be the gold standard paediatric screening protocol. The tests comprising the MCT are presented in Table 2.5-1.

Table 2.5-1

<table>
<thead>
<tr>
<th>Tests included in the Orinda MCT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Monocular visual acuity</strong></td>
</tr>
<tr>
<td>Charts (letters and illiterate E) at 20 feet (6 metres)</td>
</tr>
<tr>
<td><strong>Cover test - distance and near</strong></td>
</tr>
<tr>
<td>Cover-uncover and alternate-cover tests; 5Δ loose prism used for determination of the cut-off point for distance and 6Δ and 10Δ loose prisms used for near</td>
</tr>
<tr>
<td><strong>Retinoscopy</strong></td>
</tr>
<tr>
<td>Retinoscopy performed with lens bar (-0.75D, +0.75D, +1.50D and +2.25D) whilst child viewed a cartoon film at 20 feet (6 metres) through +1.50D lenses</td>
</tr>
<tr>
<td><strong>Assessment for ocular pathology</strong></td>
</tr>
<tr>
<td>A hand magnifier and ophthalmoscope used to check for external and internal ocular pathology</td>
</tr>
</tbody>
</table>

2.5.3 VISION SCREENING PROGRAMS CURRENTLY IN USE IN AUSTRALIA

Many different paediatric vision screening programs are currently operational in Australia although there is little coordination, and a lack of consensus on how and when children should be screened, based on the different guidelines between states and territories (Morcos & Wright, 2009). Each Australian state and territory has separate Health Department guidelines (Appendix B). The terminologies used in Appendix B are those employed within each set of guidelines; the differences in terminology and the overall absence of terminology definitions further emphasises
the lack of coordination between states and territories in regard to vision screening. Nevertheless, amblyopia and strabismus are the focus of most protocols, although risk factors for their development, such as anisometropia and uncorrected hyperopia, are largely overlooked. Many other relatively common visual conditions such as accommodation and/or vergence disorders, refractive errors not affecting visual acuity (some hyperopia and astigmatism), and ocular health problems are also absent from many of the state-based protocols.

Vision screenings are also conducted at some primary and secondary schools by local optometrists. These are performed in an ad hoc manner that is likely to be driven by the individual optometrist’s interest in paediatric vision and by their available time. As such, screening programs provided by optometrists result in an important but unmeasured and geographically inconsistent service provision in the community. This conclusion is supported by one of the findings of the NVCSP which identified very few studies that included optometrists in the screening process, despite the significant role they are assumed to play in this regard. As a result of the inconsistent distribution of screening resources in Australia, a coordinated, co-management system has been suggested – this strategy proposes that child and family health nurses, optometrists, orthoptists and GPs all play a role as primary screeners (Morcos & Wright, 2009). Importantly, despite this recommendation by the NVCSP, little evidence has emerged since that review to show that it is being implemented.

2.5.4 CONCLUSION

It has been demonstrated that there is no universally agreed policy or strategy for vision screening in children. This is likely to be a consequence of the paucity of evidence supporting the benefits of screening as well as inconsistent levels of support from relevant authorities and poorly coordinated and irregularly distributed service provision involving multiple health professions.

A published paper by the author of this thesis and her supervisors was based on an extensive review of the current guidelines surrounding children’s vision screenings in Australia and is included in Appendix A. Copyright permission has been obtained to present the published paper in this thesis.
2.6 SUMMARY AND IMPLICATIONS

There is little published data on the visual profile and prevalence of vision conditions in Australian Indigenous children. Refractive error range, prevalence of vision conditions such as accommodation and/or vergence disorders, strabismus, amblyopia and visual information processing disorders in Australian Indigenous children have not been extensively researched. Furthermore, research has shown that uncorrected hyperopia, binocular vision disorders such as accommodation and/or vergence disorders and visual information processing skills may be related to reduced educational performance in children. With the recent emphasis on the lower literacy skills of Indigenous children, and the Federal Government’s target of halving the literacy and numeracy gap between Indigenous and non-Indigenous school children, identifying the prevalence of vision conditions associated with learning is critical. Establishment of a visual profile for Australian Indigenous children is vital in order to determine whether these children are being disadvantaged in the classroom as a result of undetected and/or untreated vision conditions. Finally, timely detection of these vision conditions is also required; a coordinated and widespread vision screening service that is designed to target such conditions will assist in their earlier detection.
Chapter 3: Validation of cycloplegic retinoscopy for measurement of refractive error

This chapter presents two papers (one published and one under review) that discuss the results of a preliminary study performed as part of this research program. The two studies were designed to determine the most appropriate method for measuring refractive error in children in school-based research studies. This was necessary given that there was no consistency in the literature with regards to the preferred technique; with many different refractive error measurement techniques having been used in paediatric studies. The findings from the preliminary study have directly informed the selection of the method used for determining refractive error in the main study.

A number of different methods and techniques are used to measure refractive error in children. Adequate accommodation control is particularly important when measuring refractive error in this group, as inadequate accommodation control can significantly affect the results, specifically in terms of underestimation of hyperopia, which is relatively common in school-aged children.

The repeatability of a technique also needs to be considered when selecting the most appropriate method for measuring refractive error, as this provides a measure of the spread of values obtained over repeated measurements for one particular method. Techniques with poor repeatability reduce the confidence that can be placed on a single measure – this confidence is critical in both the research and clinical contexts.

The first paper considers two different methods of accommodation control (fogging and cycloplegia) measured with two different techniques (autorefraction and retinoscopy). Cycloplegia (which temporarily paralyses the ciliary muscle, and therefore accommodation) was selected as it has frequently been cited as the gold standard for controlling accommodation in children. Fogging (which relaxes accommodation through the use of positive powered lenses) was selected to determine whether it was a suitable alternative to cycloplegia, in order to reduce the disadvantages associated with performing cycloplegia on children, such as
discomfort to patient and time taken for the effect of cycloplegia to wear off. Retinoscopy and autorefraction are two refractive error measurement techniques commonly performed in children; the background of these techniques is presented in the following two papers. The first paper reports which method (fogging or cycloplegia) is most effective at controlling accommodation. The aim of the second paper was to determine which measurement technique (autorefraction or retinoscopy) was more repeatable using the most effective accommodation control method, as determined in the first paper.

Copyright permission has been obtained to present the published paper in this thesis. Figure, table and section numbering has been edited to maintain consistency with the format of the thesis.

3.1 REFRACTION IN CHILDREN: A COMPARISON OF TWO METHODS OF ACCOMMODATION CONTROL


3.1.1 ABSTRACT

Purpose: The prevalence of refractive errors in children has been extensively researched. Comparisons between studies can, however, be compromised because of differences between accommodation control methods and techniques used for measuring refractive error. The aim of this study was to compare spherical refractive error results obtained at baseline and using two different accommodation control methods – extended optical fogging and cycloplegia, for two measurement techniques – autorefraction and retinoscopy.

Methods: Participants comprised twenty-five school children aged between six and thirteen years (mean age: 9.52 ± 2.06 years). The refractive error of one eye was measured at baseline and again under two different accommodation control conditions: extended optical fogging (+2.00DS for twenty minutes) and cycloplegia (1% cyclopentolate). Autorefraction and retinoscopy were both used to measure most plus spherical power for each condition.

Results: A significant interaction was demonstrated between measurement technique and accommodation control method (\(p = 0.04\), with significant differences
in spherical power evident between accommodation control methods for each of the measurement techniques ($p = 0.01$). For retinoscopy, refractive errors were significantly more positive for cycloplegia compared to optical fogging, which were in turn significantly more positive than baseline. For autorefraction, there were significant differences between cycloplegia and extended optical fogging and between cycloplegia and baseline only.

**Conclusions:** Determination of refractive error under cycloplegia elicits more plus than using extended optical fogging as a method to relax accommodation. These findings support the use of cycloplegic refraction compared with extended optical fogging as a means of controlling accommodation for population based refractive error studies in children.

**Key words:** refractive error, children, methodology, retinoscopy, autorefraction, cycloplegia, fogging technique

### 3.1.2 INTRODUCTION

The prevalence of paediatric refractive errors has been extensively researched, with many studies reporting refractive error data for school age children (from 4 – 17 years), (Azizoglu, Junghans, Barutchu, & Crewther, 2010; Ip, Robaei, et al., 2008; Ip, Rose, Morgan, Burlutsky, & Mitchell, 2008; Junghans & Crewther, 2005; Kleinsteijn et al., 2003; Maul, Barroso, Munoz, Sperduto, & Ellwein, 2000; Negrel, Maul, Pokharel, Zhao, & Ellwein, 2000; Ojaimi, Rose, Smith, et al., 2005; Ojaimi, Rose, Morgan, et al., 2005; Pokharel, Negrel, Munoz, & Ellwein, 2000; Zhao et al., 2000), as well as in pre-school age children (6 – 72 months), (Dirani, Chan, et al., 2010; Giordano et al., 2009; Multi-Ethnic Pediatric Eye Disease Study Group, 2010; Pai et al., 2012; Pai, Samarawickrama, Burlutsky, & Mitchell, 2010). Comparison between these studies is, however, potentially compromised because of differences in the accommodation control methods used (non-cycloplegia and cycloplegia) as well as the techniques used for measuring refractive error (autorefraction and retinoscopy), (Ojaimi, Rose, Smith, et al., 2005).

The gold standard for measuring refractive error in children’s population studies is with cycloplegia (Erdurmus, Yagci, Karadag, & Durmus, 2007; Steele, Ireland, & Block, 2003; Twelker & Mutti, 2001; Williams, Lumb, Harvey, & Sparrow, 2000), due to its ability to control accommodation. Inadequate control of
accommodation can impact refractive error measurements in children, particularly with regards to hyperopia (Junghans & Crewther, 2005). Non-cycloplegic measurements, using either autorefrraction or retinoscopy, have been shown to underestimate the hyperopic refractive state of a child; this underestimation is referred to as latent error (Suryakumar & Bobier, 2003). Many studies have measured latent error and report values ranging from 0.1 dioptres to two dioptres (Chan & Edwards, 1994; Shultz, 1975; Suryakumar & Bobier, 2003; Young et al., 1971). High latent errors have been shown to be associated with higher levels of hyperopia and also vary according to the target and instrument design selected for the measurement of refractive error (Suryakumar & Bobier, 2003).

However, there are a number of disadvantages associated with cycloplegia, including time, discomfort, cost, and inconvenience. Accordingly, cycloplegic refractions have not always been the method of choice in research settings, which creates a problem with population studies where comparisons are compromised by the different methods adopted to measure refractive errors.

Optical fogging provides an alternative method of measuring refractive error, where accommodation is controlled by adding positive lenses in front of the eyes, to relax accommodation (Campbell, Benjamin, & Howland, 2006; Grosvenor, 2002; Heath, 1956; Suryakumar & Bobier, 2003; Ward & Charman, 1987). Studies have compared retinoscopy performed with optical fogging to cycloplegic retinoscopy, however, the method by which the optical fogging was performed was either not described (Azizoglu et al., 2010), or the amount of fogging varied between studies: +1.50D fogging lenses were used in one study (Chan & Edwards, 1994) whilst increasing amounts of plus lens power applied in a stepwise procedure were used in another (Suryakumar & Bobier, 2003).

One method of optical fogging involves the use of additional plus lenses over the habitual refraction for an extended period of time to relax accommodation. In this instance, optical fogging should reduce visual acuity to no worse than 6/60, unless large astigmatic errors exist; and it has been suggested that up to ten or fifteen minutes may elapse before satisfactory relaxation of accommodation has occurred (Kaufman, 1980). Accommodation could therefore theoretically be relaxed by the participant viewing a distance target for a twenty minute time period through +2.00D lenses. A twenty minute time period was nominated because it was considered a
sufficiently conservative amount of time to relax accommodation (Kaufman, 1980),
whilst having the advantage of being shorter than the time required for the onset of
cycloplegic agents. In addition, it does not have the inconvenience of paralysing the
child’s accommodation and dilating their pupils for several hours after testing,
should it prove to be a viable alternative as an accommodation control method. This
particular optical fogging technique that includes an extended period of adaptation to
blur has not previously been compared with other methods of accommodation
control such as cycloplegia.

In this study, we compared spherical refractive error results measured at
baseline and using two different accommodation control methods: extended optical
fogging and cycloplegia in children. Autorefraction and retinoscopy were used to
measure the most plus spherical refractive power, with the aim of determining
whether extended optical fogging was comparable to cycloplegia for either or both
measurement techniques. If the extended optical fogging technique proved to be
comparable to cycloplegia, it could provide an effective alternative, therefore
minimising discomfort and disruption to school and leisure activities for children
participating in these studies.

3.1.3 MATERIALS AND METHODS

Twenty five school children (seven male, eighteen female) aged between six
and thirteen years (mean age: 9.52 years ± 2.06) were recruited from the Queensland
University of Technology (QUT) Optometry clinic database as well as family and
friends of academic staff members of the school. All children had best-corrected
visual acuities of 6/7.5 or better.

The study was conducted in accordance with the tenets of the Declaration of
Helsinki and was approved by the Queensland University of Technology Human
Research Ethics Committee. All participants and their guardians were given a full
explanation of the experimental procedures. Written informed consent was obtained
from both the participant and their guardian prior to involvement, with the option to
withdraw from the study at any time.

Vision testing was undertaken at the QUT Optometry clinic, and all
autorefracton and retinoscopy measurements (using a phoropter) were performed by
one investigator who was an experienced optometrist (author SH). A research
assistant contributed to the data collection process, as retinoscopy measurements were acquired under masked conditions. The research assistant altered the phoropter settings under instruction from the investigator, ensuring that the latter was unaware of the lens powers in the phoropter. It was not necessary to mask autorefracti
results as it is an objective measure that could not be affected by inadvertent bias. In addition, knowledge of the autorefraction result could not affect retinoscopy outcomes as the investigator performing retinoscopy had no knowledge of the spherical power that had been randomly dialled into the phoropter by the research assistant and was therefore masked to the results of their own retinoscopy throughout data collection.

The refractive error of one eye was measured at baseline and then under two different accommodation control conditions: extended optical fogging (+2.00DS for twenty minutes) and cycloplegia (1% cyclopentolate). Autorefraction was performed first followed by retinoscopy at baseline and then for each of the accommodation control conditions.

An open-field autorefractor (Shin-Nippon SRW-5000) was used for all autorefraction measurements. This autorefractor uses an open-view arrangement, which enables unrestricted binocular view of a distance target (Choong, Chen, & Goh, 2006). It therefore differs from other autorefractors, which use automated fogging mechanisms to control accommodation. Automated fogging mechanisms have not been found to adequately control the patient’s accommodation in some cases, and the fixation target may induce instrument myopia (Jorge, Queiros, Gonzalez-Mejome, et al., 2005).

**Baseline**

Baseline measurements of refractive error were completed for autorefraction and retinoscopy prior to performing extended optical fogging and cycloplegia.

**Extended optical fogging**

Participants who did not normally wear spectacles were required to wear +2.00DS lenses binocularly whilst watching a twenty minute video on a fifteen inch screen at a working distance of two metres. This distance ensured that participants were able to view the screen with sufficient detail to maintain attention for the twenty minute period. As none of these participants were uncorrected hyperopes of
greater than +1.00DS, the +2.00DS spectacles sufficiently fogged the two metre viewing target.

Participants who did wear spectacles had +2.00DS added to their spectacle correction and lenses of these powers were placed in a trial frame. The refractive power of the participant’s spectacles was measured and compared against the non-cycloplegic retinoscopy to assess for under-corrected manifest hyperopia – to ensure adequate fogging was achieved with the addition of +2.00DS lenses. The participant viewed the same twenty minute video at a distance of two metres through these lenses.

The +2.00DS lenses were removed immediately before the autorefraction and retinoscopy measurements were performed and were put back on as the participant moved between tests, to ensure that no regression occurred of the accommodative effect achieved with the fogging lenses.

**Cycloplegia**

Cyclopentolate 1% administered as a spray to the closed eye-lid was used to achieve cycloplegia. The spray application has been shown to produce equivalent cycloplegia to eye drops (Ismail & Rouse, 1994). The cycloplegic spray was administered provided the participant reported no history of allergic reactions to mydriatic agents, and the anterior chamber angle was shown to be open. After twenty minutes, if pupil reactivity was still present, a second spray was administered. Pupil reactivity and diameter were recorded at least 25 minutes after the first spray. Cycloplegia was considered complete when the pupil was both non-reactive to light and had a minimum diameter of 6mm according to recommended protocols (Negrel et al., 2000; Zhao et al., 2004).

**Autorefraction**

The distance fixation target for autorefraction (performed in a three metre room) was a 6/150 symbol (plus sign) and was positioned such that the optical axis of the instrument and the participant’s line of sight when viewing the target were aligned. The large fixation target of a black plus sign on a plain white wall was selected as it would not provide a strong stimulus for accommodation. The participant was seated comfortably with their chin on the chin-rest, head against the
forehead rest, eyes level with the eye mark and viewed binocularly the fixation target through the window.

Five repeated measurements were performed on the selected eye and the mean was calculated (using most plus spherical power result).

**Retinoscopy**

Working distance lenses of +1.50D were used, whilst the participant viewed a 6/60 letter at six metres. With the spherical power dial masked, a research assistant randomly dialled in a spherical power, whilst the investigator neutralised the beam; this procedure was repeated five times. The mean of the most plus spherical power was calculated from the five repeated measurements.

**Statistical analysis**

Statistical analysis was performed using SPSS 18.0 (SPSS Inc., Chicago, IL). For all statistical tests, a $p$-value $<0.05$ indicated a statistically significant difference. A clinically significant difference was considered to be $\geq 0.25$D mean difference between the different methods (Goss & Grosvenor, 1996).

A 2 x 3 repeated measures ANOVA with the factors of measurement technique (two levels: retinoscopy, autorefractor) and accommodation control (three levels: baseline, extended optical fogging and cycloplegia) was conducted for the most plus spherical power results. Follow-up one way ANOVAs were conducted comparing accommodation control methods for each measurement technique, which included pair-wise comparisons adjusted for family-wise error using the Bonferroni method.

### 3.1.4 RESULTS

The range in refractive errors was -1.40D to +1.05D, median = +0.25D. Sixty percent of participants had brown irides, 32% had blue irides and the remaining 8% had hazel irides. There was no significant relationship between latent error (increase in hyperopic refractive error with cycloplegia) and iris colour ($F(2, 22) = 0.78, p = 0.47$). Group mean data (and standard error) for the most plus spherical power results obtained at baseline and under the two accommodation methods (extended optical fogging and cycloplegia) are presented in Figure 3.1-1 for both autorefraction and retinoscopy. Results from the 2 x 3 repeated measures ANOVA showed that there was a statistically significant interaction between measurement technique and accommodation control method ($F(2, 23) = 3.86, p = 0.04$).
Follow-up one way ANOVAs comparing spherical power as a function of accommodation control showed a significant difference between accommodation control methods for both measurement techniques (retinoscopy: $F(2, 23) = 7.00, p < 0.01$; autorefraction: $F(2, 23) = 17.38, p < 0.01$). Pairwise comparisons, adjusted for multiple comparisons (Bonferroni) demonstrated significant differences between all three conditions (baseline, extended optical fogging and cycloplegia) for retinoscopy. For the autorefraction measurements, there was a significant difference between cycloplegia and extended optical fogging, and also between cycloplegia and baseline; however there was no significant difference between baseline and extended optical fogging. Additionally the retinoscopy and autorefractor measurements were significantly different under cycloplegia (autorefraction resulted in a more positive spherical power, $t(24) = 3.03, p = 0.01$), but not at baseline or after extended optical fogging; mean differences (± standard deviation) between autorefraction and retinoscopy at baseline and under the two accommodation control methods were: 0.07D ± 0.45 (baseline), 0.11D ± 0.46 (extended optical fogging) and 0.27D ± 0.44 (cycloplegia).

\[\text{Figure 3.1-1. Most plus spherical power results for retinoscopy and autorefraction}\]
Chapter 3: Validation of cycloplegic retinoscopy for measurement of refractive error

3.1.5 DISCUSSION

This study has shown that determination of refractive error under cycloplegia elicits a relatively more positive spherical power than using extended optical fogging as a method to relax accommodation in school-aged children.

The most plus spherical outcomes obtained under cycloplegia were also more positive than baseline. As such, our results agree with those reported in other studies comparing cycloplegic and non-cycloplegic results, where the mean spherical power was also significantly less hyperopic without cycloplegia (Chan & Edwards, 1994; Fotedar et al., 2007; Rotsos, Grigoriou, Kokkolaki, & Manios, 2009; Suryakumar & Bobier, 2003; Zhao et al., 2004). This, however, is the first study to compare cycloplegia with extended optical fogging. Theoretically, whilst extended optical fogging should be an effective method of accommodation control our results show it to be less effective than cycloplegia for this group of school-aged children. Although it has been reported that the fogging technique is a valid method of controlling accommodation for low levels of fogging (Ward & Charman, 1987), another study found varying results with optical fogging (Reese & Fry, 1941). Furthermore, in the first study (Reese & Fry, 1941), as the level of fogging was increased, some participants maintained a relaxed and stable accommodative state, whilst some demonstrated increased accommodative activity and others decreased accommodative activity. This suggests that optical fogging may not provide a consistent method for controlling accommodation for moderate to high levels of fog, as the accommodative response to optical fogging has been shown to vary between participants. It is possible that the varying results found with optical fogging were a consequence of varying levels of latent hyperopia amongst the participants – resulting in different levels of fogging, and thus different effects on the accommodative state. One disadvantage of optical fogging (particularly in children) is that latent hyperopia may affect the refractive outcome if sufficient fogging is not ensured. This may be a problem in a vision screening setting, where the refractive error is unknown.

In the current study, it was found that there was a hyperopic shift in spherical power when measured with extended optical fogging compared with baseline. However, a significantly more hyperopic difference existed between the cycloplegic
and extended optical fogging condition, suggesting that cycloplegia is the most effective method for controlling accommodation.

Interestingly, there was a significant interaction between accommodative control method and measurement technique, which is represented as the difference in slopes in Figure 3.1-1. Thus, for the cycloplegic condition only, autorefraction yielded marginally but significantly more positive results than did retinoscopy. This difference between the two techniques and the significant interaction are most likely the result of two factors: i) larger cylinder measurements were recorded with autorefraction compared with retinoscopy (autorefractor cylinder was more than retinoscopy cylinder in 24/25 participants) artificially elevating the most plus spherical results and ii) the propensity for the autorefractor to relatively underestimate plus under non-cycloplegic conditions thus creating a larger difference in spherical power from baseline to cycloplegia for autorefraction compared with retinoscopy (Suryakumar & Bobier, 2003). The difference in room size between techniques also has the potential to have a minimal effect on baseline measurement differences. Our finding of greater cylinder powers measured with autorefraction compared with retinoscopy is in agreement with other studies (El-Defrawy, Clarke, Belec, & Pham, 1998; Prabakaran et al., 2009).

One limitation of this study is the relatively small range of refractive error of the participants. It is possible that the true difference between cycloplegia and extended optical fogging may have been underestimated as it is has previously been shown that latent error increases with increasing refractive error (Suryakumar & Bobier, 2003).

Although cycloplegic retinoscopy is commonly used to measure refractive error in children, it requires trained personnel to perform the technique. Autorefration, for this reason, is often used in children’s refractive error studies as it can be performed by untrained personnel. As such, it is useful to investigate whether autorefration provides equivalent quality data to retinoscopy (Steele et al., 2003). Many authors have reported on the repeatability of autorefraction and retinoscopy in children; with variable estimates reported in the case of retinoscopy (Chan & Edwards, 1994; Chat & Edwards, 2001; Harvey, Miller, Dobson, Tyszko, & Davis, 2000; Safir, Hyams, Philpot, & Jagerman, 1970; Zadnik, Mutti, & Adams, 1992). In one study conducted with forty adult participants, the repeatability of retinoscopy
under cycloplegia was poorer when compared with non-cycloplegic retinoscopy. The authors proposed that there was greater ambiguity in the retinoscopic reflex from a dilated pupil compared with a small pupil resulting in a reduction in the repeatability of the measurements (Zadnik et al., 1992). This reported difference in the repeatability of retinoscopy between cycloplegic and non-cycloplegic measurements may not be the case in children, however, as the difference in pupil size between the dilated and non-dilated eye is less. It is also likely that the differences in the repeatability of retinoscopy between studies result from differences in skill level between retinoscopists, given that the accuracy of retinoscopy results is strongly reliant on the ability of the person performing the retinoscopy. Further investigations directly comparing the repeatability of autorefraction (open-field) and retinoscopy under cycloplegia are currently underway within this participant group to confirm a preferred method for determining refractive error in paediatric population studies.

In summary, this study has demonstrated that extended optical fogging is less effective than cycloplegia in controlling accommodation in school age children. This finding confirms that cycloplegic refraction methods should remain the gold standard for population based paediatric refractive error studies. The question of whether autorefraction or retinoscopy should be adopted as the technique of choice to measure refractive error under cycloplegic conditions remains unresolved as both techniques are frequently reported in the literature – the selection of one as the gold standard would be optimal, to enable inter-study comparisons of refractive error in children.

3.1.6 ACKNOWLEDGMENTS

This work was supported by the Institute of Health and Biomedical Innovation, Queensland University of Technology. The authors thank all of the subjects who participated in the study and Tina Huynh for assistance with data collection.
3.2 REPEATABILITY OF RETINOSCOPY AND AUTOREFRACtion IN CHILDREN


3.2.1 ABSTRACT

**Purpose:** The aim of this study was to compare the repeatability of retinoscopy and autorefraction in the assessment of refractive error under cycloplegic and non-cycloplegic conditions in school-aged children. Outcomes will assist in determining which is the most appropriate technique for measuring refractive error in paediatric populations.

**Methods:** Twenty-five school children aged between six and thirteen years (mean age: 9.52 ± 2.06 years) were included in the study. Autorefraction and retinoscopy were performed on one eye under non-cycloplegic and cycloplegic conditions by an experienced optometrist. Five repeated measurements of spherical power in the highest positive meridian were recorded using each technique under both non-cycloplegic and cycloplegic conditions. The intraclass correlation coefficient (ICC) was used as a measure of repeatability.

**Results:** For each technique, cycloplegic ICC values were higher compared to non-cycloplegic values. Retinoscopy ICC outcomes showed good to excellent repeatability (0.95 under cycloplegic conditions and 0.86 non-cycloplegic conditions), whilst the repeatability of autorefraction was lower, but still considered to be good (0.81 [cycloplegia] and 0.71 [non-cycloplegia]).

**Conclusions:** Retinoscopy was shown to be more repeatable than autorefraction when measuring refractive error in school-aged children under both cycloplegic and non-cycloplegic conditions. The results also show that retinoscopy under cycloplegia is more repeatable than retinoscopy under non-cycloplegic conditions. This suggests that cycloplegic retinoscopy, when performed by an experienced retinoscopist, is the optimal technique for measuring refractive error in school-aged children.

**Key words:** refractive error, children, methodology, repeatability, retinoscopy, autorefraction, cycloplegia
3.2.2 INTRODUCTION

The use of cycloplegia is generally agreed to be the gold standard for the measurement of refractive error of children in prevalence studies (Erdurmus et al., 2007; Funaran, Tengtrisorn, Sangsupawanitch, & Siangyai, 2009; Hopkins, Sampson, Hendicott, Lacherez, & Wood, 2012; Twelker & Mutti, 2001; Williams et al., 2000). However, while numerous prevalence studies of child populations have been undertaken (Azizoglu et al., 2010; Dirani, Chan, et al., 2010; Giordano et al., 2009; Junghans & Crewther, 2005; Kleinstein et al., 2003; Maul et al., 2000; Multi-Ethnic Pediatric Eye Disease Study Group, 2010; Ojaimi, Rose, Smith, et al., 2005; Pai et al., 2012; Pokharel et al., 2000; Zhao et al., 2000), not all have used cycloplegia. There is a lack of consistency regarding the techniques that have been used to measure refractive error, with retinoscopy and autorefraction being the most common objective techniques, which makes it difficult to directly compare study outcomes. Cycloplegia has been shown to elicit more latent hyperopia than alternative approaches for both retinoscopy and autorefraction (Hopkins et al., 2012). However, there is disagreement as to whether retinoscopy or autorefraction is the optimal technique to provide repeatable data under cycloplegic conditions. Retinoscopy has been reported to be a repeatable technique in some studies, and not in others (Chan & Edwards, 1994; Zadnik et al., 1992).

Traditionally, retinoscopy has been the preferred technique for determining refractive error in children, and is still the predominant method used in clinical practice (Prabakaran et al., 2009). More recently, autorefraxion has provided a viable alternative. Compared with retinoscopy, autorefraxion has a shorter testing time, does not need to be administered by a qualified eye-care practitioner, and has been reported to be less subject to inter-observer variability (Prabakaran et al., 2009; Steele et al., 2003). Most autorefractors provide a single refractive error value based on multiple measurements; variability however, can still exist, both within these separate measures taken by the instrument and potentially between different instruments. Furthermore, a single estimate of refractive error is only useful if it provides a precise and reliable measure. This is an issue both in a clinical setting and for population based studies.

Repeatability provides a measure of a technique’s precision (Bland & Altman, 1999); where precision refers to the closeness (or spread) of values obtained on
repeated measurements obtained by the same method (Mantha, Roizen, Fleisher, Thisted, & Foss, 2009). A technique with poor repeatability reduces the confidence with which a single measure can be viewed. While the issue of repeatability in terms of refractive error measurement is critical (for both clinical and research purposes), few studies have addressed the repeatability of these two commonly used measurement techniques (Rosenfield & Chiu, 1995; Zadnik et al., 1992). A small number of studies have reported on the repeatability of retinoscopy or open-field autorefraction in children (Chan & Edwards, 1994; Chat & Edwards, 2001; Safir et al., 1970); however, none have directly compared the repeatability obtained for each technique on the same sample group. In other studies which have compared refractive errors determined using different refractive error measurement techniques, the repeatability of each individual technique was not reported (Oral, Gunaydin, Ozgur, Arsan, & Oskan, 2012; Salvesen & Kohler, 1991).

The aim of this study was to compare the repeatability of retinoscopy and autorefraction both under cycloplegic and non-cycloplegic conditions in school-aged children, in order to assist in determining the optimal method for measuring refractive error in children’s studies.

### 3.2.3 MATERIALS AND METHODS

Twenty five school children (seven male, eighteen female) aged between six and thirteen years (mean age: 9.52 ± 2.06 years) were recruited from the Queensland University of Technology (QUT) Optometry clinic database as well as family and friends of academic staff members of the school (Hopkins et al., 2012). All children had corrected visual acuities of 6/7.5 or better in each eye. The study was conducted in accordance with the tenets of the Declaration of Helsinki and was approved by the Queensland University of Technology Human Research Ethics Committee. All participants and their guardians were given a full explanation of the experimental procedures. Written informed consent was obtained from both the participant and their guardian prior to involvement, with the option to withdraw from the study at any time.

Vision testing was undertaken at the QUT Optometry clinic, and all autorefraction and retinoscopy measurements were performed by a single investigator who is an experienced optometrist (author SH). A research assistant
altered the phoropter settings under instruction from the investigator, ensuring that the latter was masked to the lens power used at each stage.

Five repeated measurements were taken on one eye for autorefraction and retinoscopy under non-cycloplegic and then cycloplegic conditions. Cyclopentolate 1% administered as a spray to the closed eyelid was used to achieve cycloplegia. The spray application has been shown to produce equivalent cycloplegia to eye drops (Ismail & Rouse, 1994). The cycloplegic spray was administered provided the participant reported no history of allergic reactions to anti-muscarinic agents, and the anterior chamber angle was shown to be open. Cycloplegia was considered complete when the pupil was both non-reactive to light and had a minimum diameter of six millimetres (Negrel et al., 2000; Zhao et al., 2004). After twenty minutes, if pupil reactivity was still present, a second spray was administered. Pupil reactivity and diameter were recorded at least 25 minutes after the first spray.

**Autorefraction**

An open-field autorefractor (Shin-Nippon SRW-5000) was used for all measurements. This autorefractor uses an open-view arrangement, which enables unrestricted binocular view of a distance target (Choong et al., 2006). The distance fixation target (three metre room) was a 6/150 symbol and was positioned such that the optical axis of the instrument and the participant’s line of sight when viewing the target were aligned. The large fixation target of a black plus sign on a plain white wall was selected so as to not provide a strong stimulus for accommodation. Five repeated measurements were performed and the mean was calculated for each participant (using the most plus spherical power result), (Hopkins et al., 2012). The repeatability of cylinder power and axis was not assessed for either autorefraction or retinoscopy measurements, as it was not possible to accurately mask the retinoscopist to the cylinder axis measurements using the current study design.

**Retinoscopy**

Binocular working distance lenses of +1.50D were used, whilst the participant viewed a 6/60 letter at six metres. With the spherical power dial masked, a research assistant randomly dialled in a spherical power, whilst the investigator neutralised the retinoscopy reflex; this procedure was repeated five times. The mean of the most plus spherical power meridian was calculated from the five repeated retinoscopy measurements.
Statistical analysis

Statistical analysis was performed using SPSS 18.0 (SPSS Inc., Chicago, IL). The intraclass correlation coefficient (ICC) was used as a measure of repeatability. The ICC represents the proportion of total variability that can be attributed to ‘true variability’ (between subjects) as opposed to ‘error’ (within subjects or between measurements). A high value of the ICC represents a measure that differs considerably between individuals, but little between measurements. For techniques showing strong repeatability, the ICC will be high.

3.2.4 RESULTS

Five repeated measurements of spherical power in the highest positive meridian were recorded using retinoscopy and autorefraction under both non-cycloplegic and cycloplegic conditions. Summary statistics for all four measurement conditions are shown in Table 3.2-1.

<table>
<thead>
<tr>
<th>Measurement condition</th>
<th>Mean ± sd; range (dioptres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-cycloplegic retinoscopy</td>
<td>+0.16 ± 0.50; -1.50 to +1.00</td>
</tr>
<tr>
<td>Non-cycloplegic autorefraction</td>
<td>+0.22 ± 0.34; -0.50 to +0.75</td>
</tr>
<tr>
<td>Cycloplegic retinoscopy</td>
<td>+0.51 ± 0.68; -1.50 to +1.50</td>
</tr>
<tr>
<td>Cycloplegic autorefraction</td>
<td>+0.78 ± 0.55; -0.75 to +2.00</td>
</tr>
</tbody>
</table>

Retinoscopy had higher ICC values than autorefraction for both conditions. For each technique, cycloplegic ICC values were higher than non-cycloplegic values. Retinoscopy ICC outcomes showed good to excellent repeatability (defined as ICC ≥ 0.75), (Orlansky et al., 2011) whilst autorefraction repeatability had ICC values that represent good repeatability (≥ 0.55). Intraclass correlation coefficients (ICC) are presented in Table 3.2-2.
### Table 3.2-2

*Intraclass correlation coefficient (ICC) and repeatability coefficients for retinoscopy and autorefraction (non-cycloplegia and cycloplegia)*

<table>
<thead>
<tr>
<th></th>
<th>ICC (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cycloplegia</strong></td>
<td></td>
</tr>
<tr>
<td>Retinoscopy</td>
<td>0.95 (0.92 – 0.98)</td>
</tr>
<tr>
<td>Autorefraction</td>
<td>0.73 (0.59 – 0.87)</td>
</tr>
<tr>
<td><strong>Non-cycloplegia</strong></td>
<td></td>
</tr>
<tr>
<td>Retinoscopy</td>
<td>0.86 (0.77 – 0.96)</td>
</tr>
<tr>
<td>Autorefraction</td>
<td>0.71 (0.56 – 0.86)</td>
</tr>
</tbody>
</table>

The group mean values versus standard deviation for the five measures used to calculate repeatability were plotted individually for each participant and are shown in Figure 3.2-1, Figure 3.2-2, Figure 3.2-3 and Figure 3.2-4 for all four conditions. The shape of the plots varies between the cycloplegic and non-cycloplegic measurements (along the horizontal axis), reflecting the greater spread of refractive error measurements obtained under cycloplegia – i.e. higher positive powers recorded under cycloplegia increased the spread. These plots confirmed that the standard deviation was unrelated to the magnitude of the measurement, as the scatterplots showed no discernible relationship between mean and standard deviation for any of the four datasets. This indicates that the precision of the measures did not depend on the level of refractive error in this sample.
Figure 3.2-1. Mean versus standard deviation for the five repeat measures recorded for each participant with non-cycloplegic retinoscopy

Figure 3.2-2. Mean versus standard deviation for the five repeat measures recorded for each participant with cycloplegic retinoscopy
Chapter 3: Validation of cycloplegic retinoscopy for measurement of refractive error

3.2.5 DISCUSSION

This study compared the repeatability of retinoscopy and autorefraction in school-aged children. Results show that retinoscopy, when undertaken by an experienced optometrist, is more repeatable than autorefraction in measuring refractive error in children, under both cycloplegic and non-cycloplegic conditions.

Figure 3.2-3. Mean versus standard deviation for the five repeat measures recorded for each participant with non-cycloplegic autorefraction

Figure 3.2-4. Mean versus standard deviation for the five repeat measures recorded for each participant with cycloplegic autorefraction
The results also demonstrate that retinoscopy under cycloplegia is more repeatable than retinoscopy under non-cycloplegic conditions.

While a number of authors have compared refractive errors determined using different refractive error measurement techniques in children (Choong et al., 2006; Oral et al., 2012; Prabakaran et al., 2009; Salvesen & Kohler, 1991), repeatability of the techniques in these studies was not reported. A limited number of studies have reported repeatability of individual refractive error measurement techniques in studies where methods have been compared; however these studies were only performed on adult populations (Rosenfield & Chiu, 1995; Zadnik et al., 1992).

Repeatability of spherical power determined by retinoscopy varies greatly between studies. Chan (1994) reported on the repeatability of retinoscopy under non-cycloplegic conditions by performing the technique twice on a sample of 3-year old children under masked conditions. Chan concluded that two individual retinoscopy measurements for this age-group were highly correlated ($r = 0.91$, $p < 0.0001$), with a mean difference between the two measures of only 0.02 dioptres, and the 95% limit of agreement between two results being between +0.53 and -0.50 dioptres (Chan & Edwards, 1994). However, these findings suggest, but do not necessarily prove, that retinoscopy has strong repeatability, given that correlation alone is a poor measure of repeatability, while ICC is considered to be the most useful index of repeatability (Bland & Altman, 1986).

Zadnik et al. (1992), in contrast, found that repeatability of both non-cycloplegic and cycloplegic retinoscopy was relatively poor and concluded that retinoscopy is a poor choice for determination of refractive error in population based studies (Zadnik et al., 1992). In Zadnik et al.’s study, retinoscopy, subjective refraction and autorefraction were measured on two separate occasions under non-cycloplegic and cycloplegic conditions on forty adults by the same examiner. The examiner’s level of experience with retinoscopy was not reported in the study; this may affect the repeatability results as it would be expected that in the case of retinoscopy, an examiner with limited experience with retinoscopy would have a lower repeatability. The repeatability of each technique was assessed by calculating the difference in the values obtained at two measurement sessions; this differs from the current study where five repeated measurements were taken at one measurement session. Cycloplegic autorefraction provided the best repeatability across occasions.
and was also unaffected by large pupil size. Retinoscopy and subjective refraction had lower repeatability than autorefraction; and for both techniques, non-cycloplegic measures were more repeatable. In the case of retinoscopy, it was presumed that an increased ambiguity of the retinoscopy reflex in a dilated pupil resulted in the lower repeatability in this adult population (Zadnik et al., 1992). In the current study, retinoscopy and autorefraction were more repeatable under cycloplegic conditions, indicating that the benefit of controlling the accommodation with cycloplegia in children outweighs the negative effects of the larger pupil size.

Under non-cycloplegic conditions, Safir et al. also reported that repeatability of retinoscopy varied significantly between ophthalmologists (inter-examiner), and that overall, there was a 90% chance of obtaining differences of up to 1.34 dioptres between repeated measures (Safir et al., 1970). In their study, five ophthalmologists of varying ages and training backgrounds performed retinoscopy on ten participants. However, Safir et al.’s study was performed on a low number of participants and did not control accommodation well. Importantly, Zadnik et al. and Safir et al.’s studies measured the repeatability of retinoscopy on adults, where additional factors such as pupil size and media clarity play a role, as opposed to the paediatric populations used in Chan’s study and the current study. It is possible, that the difference in the age groups is the reason for this discrepancy in repeatability. Clearer media and larger pupils, which are common in a paediatric sample, may result in a relative improvement in precision provided accommodation is adequately controlled. This may help to explain why the current study, as well as that of Chan, found retinoscopy to be highly repeatable in contrast with the previous adult studies. In addition, the experience level of the retinoscopists in these studies was not reported: this may differ between studies, explaining some of the variation in the repeatability reported.

The repeatability of the Shin-Nippon SRW-5000 autorefractor has been previously assessed on children aged between 4 – 8 years (Chat & Edwards, 2001). Three measurements were taken (two by one examiner, and one by a second examiner) under cycloplegic and non-cycloplegic conditions. Repeatability was higher for the cycloplegic measures, and slightly better for one examiner, compared with two. It was suggested that the inter-examiner differences were a result of differences in the criterion used for focusing the corneal reflection and that these differences may be minimised by ensuring that both examiners use the same focusing
criterion. Under cycloplegic conditions, 95% of repeated measurements did not vary by more than 0.37 dioptres, whilst 95% of repeated measurements did not vary by more than 0.51 dioptres under non-cycloplegic conditions.

One limitation of the current study is the relatively small range of refractive errors for which repeatability has been demonstrated. Figure 3.2-1, Figure 3.2-2, Figure 3.2-3 and Figure 3.2-4 nonetheless do not show a trend towards variability depending on refractive error across this range for any of the conditions. Theoretically, the precision of retinoscopy is not dependent on the degree of refractive error; reflex neutralisation should be no more or less difficult with higher errors. However there may be value in this study being repeated with participants who have a more extensive range of refractive errors.

Accuracy and repeatability of a technique are the primary factors that should govern the preferred refractive error measurement method in studies of refractive error in children. The current study has demonstrated that, under both cycloplegic and non-cycloplegic conditions, retinoscopy is more repeatable than autorefraction on school-aged children when performed by a single experienced retinoscopist. This has practical benefits from a research perspective, as retinoscopy is a compact and portable technique compared with open-field autorefraction, although it does depend on an experienced retinoscopist being part of the research team.

Future studies could compare the repeatability of retinoscopy and autorefraction in adults given that the use of cycloplegia is not as important as with children, and factors such as media opacity and pupil size begin to play a more substantial role. A comparison between inter- and intra-examiner repeatability should also be performed for these techniques. The findings of this study nonetheless suggest that, if repeatability is considered as a key factor, cycloplegic retinoscopy when performed by an experienced practitioner, is a reliable technique for measuring refractive error in school-aged children.

3.2.6 ACKNOWLEDGMENTS

We thank all of the subjects who participated in the study, Tina Huynh for assistance with data collection and Philippe Lacherez for assistance with statistical advice. This project was supported by the Institute of Health and Biomedical Innovation, Queensland University of Technology.
3.3 CONCLUSION

The findings from preliminary study presented as two separate research papers in this chapter have confirmed that cycloplegic retinoscopy is the most appropriate method for measuring refractive error in school children in the current research project. The effectiveness of cycloplegia to control accommodation compared to other methods was considered, as well as the precision of the technique. As a result, cycloplegic retinoscopy was used to determine refractive error in the main study, which is detailed in Chapters 4 and 5.
Chapter 4: Visual profile of Queensland Indigenous children

4.1 BACKGROUND

The prevalence of paediatric vision conditions, including refractive error, strabismus, accommodation and/or vergence disorders, colour vision deficiency and delayed visual information processing skills has not previously been investigated in detail in Australian Indigenous children. This is important because a number of these conditions, namely, uncorrected hyperopia, accommodation and/or vergence disorders and delayed visual information processing skills have been associated with reduced academic outcomes in the wider population. Understanding the prevalence of these conditions will assist in ensuring adequate resources are available for detecting and managing these conditions in Indigenous children. The aim of the main study was therefore to develop a profile of the visual characteristics of Queensland Indigenous children by determining the prevalence of refractive error, colour vision deficiency, strabismus, accommodation and/or vergence disorders and delayed visual information processing skills in this group, and to compare the prevalence of these eye conditions with that of their non-Indigenous peers. The vision conditions that were targeted were selected on the basis of either research evidence to suggest that the condition has a negative impact on reading performance, and/or whether the condition is routinely tested for as part of a paediatric eye examination.

4.2 RESEARCH DESIGN

4.2.1 METHODOLOGY AND RESEARCH DESIGN

Research questions

What is the prevalence of common paediatric vision conditions such as refractive error, colour vision deficiency, strabismus, accommodation and/or vergence disorders and delayed visual information processing skills in Queensland Indigenous children?
Methodology

A cross-sectional correlational study was used to address the research question. A series of measurements of visual function were recorded for Indigenous and non-Indigenous children. This method enables the observation of a number of variables at one point in time, and can therefore determine relationships between two or more variables (Fraenkel & Wallen, 1993). A necessary shortcoming of this research design is that the relationships identified are descriptive; cause and effect between variables cannot be determined using a correlational research approach. This method was selected because it comprised an important first step in developing a visual profile of Queensland Indigenous children and was practical given the timeline involved with a PhD.

A quantitative research design was selected for the main study. The independent variable was Indigenous status. The dependent variables are presented in Table 4.2-1. The selection of the binocular vision tests was based on their ability to classify accommodation and/or vergence disorders (Scheiman & Wick, 2002) while also minimising the inclusion of tests that are predominantly subjective, given the age of the participants. For this reason, accommodative facility was the only accommodative measure included. This does, however, limit the ability to classify some accommodative disorders in the participants.
A series of hypotheses were tested analysing specific dependent variables against the independent variable, Indigenous status. These hypotheses are based on findings from the small number of studies that have measured different visual parameters in Indigenous children. For some of the hypotheses, the vision condition discussed had not been investigated previously in Indigenous children. In these cases, it was hypothesised that there was no difference in the prevalence of this condition between Indigenous and non-Indigenous children, given the lack of evidence to suggest otherwise. The hypotheses and the basis for each are as follows:

- Less Indigenous children have received an eye examination in the past, given that the Indigenous population overall has a low utilisation rate of available optometric services. This is either as a result of limited physical
accessibility of the service, cultural barriers and/or a lack of education about eye health issues (Wildsoet & Wood, 1996)

- There is less vision impairment in Indigenous children. According to the National Indigenous Eye Health Survey, Indigenous children were five times less likely to have vision impairment (Taylor, Xie, et al., 2010)

- The prevalence of refractive error (that reduces distance visual acuity) is less in Indigenous children. Although this has not been reported previously, the lower levels of vision impairment in this group suggest that visual acuity-reducing refractive error would also be lower

- Strabismus is less prevalent in Indigenous children given that the prevalence of strabismus in Indigenous Australians in other studies is reportedly very low (Mann & Rountree, 1968; Paterson et al., 1998)

- The prevalence of accommodation and/or vergence disorders, refractive error that does not reduced visual acuity (hyperopia and some astigmatism) and impaired visual motor integration (VMI) and/or rapid automatised naming (RAN) is similar between Indigenous and non-Indigenous children. No other studies have investigated these vision conditions in Indigenous children. It is therefore not known whether the prevalence of these conditions would be similar or not, subsequently, a null hypothesis has been chosen.

It is important to confirm whether Indigenous children have a similar prevalence of vision conditions as non-Indigenous children. This will help inform whether more emphasis needs to be placed on the provision of optometric services to this group, and which vision conditions should be prioritised in vision screenings and routine eye examinations.

4.2.2 PARTICIPANTS

Children were recruited from four metropolitan primary schools and five rural schools. The schools invited to participate in the study were selected based on their high proportion of Indigenous children attending the school (compared with other schools in their area) and the location of the school, that is schools from both metropolitan and rural areas. The four metropolitan schools were within 10 kilometres of each other and from suburbs south of Brisbane; three of the rural
schools were from neighbouring towns within the South Burnett region of Queensland (300km west of Brisbane), while the remaining two rural schools were from Rockhampton (Central Queensland, 700km north of Brisbane). All schools were located in areas of high socio-economic disadvantage (Australian Bureau of Statistics, 2011).

Children from two different age groups were included in the study. The younger age group consisted of children from Years 1 and 2 (average age of 6 and 7 years) and the older age group was made up of children from Years 6 and 7 (average age of 11 and 12 years). These year levels were selected for two reasons: firstly, their close alignment with the age of the participants in the Sydney Myopia Study, a large Australian population-based study involving children aged between 6 and 12 years (Ojaimi, Rose, Smith, et al., 2005). Secondly, the two different age groups (Years 1 – 2 and Years 6 – 7) represent different stages of learning in primary school. The ‘learning to read’ stage generally takes place up until Year 3 and so represents the learning experiences of the Years 1 and 2 children, which is then followed by the ‘reading to learn’ stage which describes the learning experience of the children in Years 6 and 7 (Chall & Jacobs, 1983).

The target sample size selected for this project was determined using a power analysis using expected values for a number of visual parameters from previously published studies (Appendix C); the number of school children recruited in each of the Indigenous and non-Indigenous groups exceeded these targets.

4.2.3 INSTRUMENTS

Data collection consisted of a series of vision tests, a reading test and the completion of a questionnaire by the child’s parent/guardian. The vision conditions that were targeted were selected on the basis of either research evidence to suggest that the condition has a negative impact on reading performance, and/or whether the condition is routinely tested for as part of a paediatric eye examination. A description of the instruments used for each test, justification for the instrument’s selection (where applicable) and the procedure used to administer each test is detailed below. The equipment list used for this component of the study is included in Appendix D.
**History**

A questionnaire was distributed to the child’s parent/guardian approximately two weeks prior to testing (Appendix E) and collected on the day of testing. A new survey was developed so that questions involved health issues common to Australian Indigenous children. The questionnaire included questions about the child’s ocular history, general health (including ear problems and low birth weight), near visual tasks and whether the child had any symptoms of vision problems or asthenopia. There were no pre-existing vision questionnaires specific to Australian Indigenous children available, despite extensive searching of relevant literature.

The questionnaire was designed to be completed by either the child’s parent/guardian or the child (supervised self-completion). The advantage of using a self-completion questionnaire was that it enabled a large number of responses to be returned; this provided wider coverage within the study population, including those who may have been reluctant to be interviewed in person or by telephone. Self-completion questionnaires also allowed the respondents to have time to consult documents as required to answer some of the questions. The length of the questionnaire was limited to one page with the majority of questions being ‘closed questions’, making the questionnaire as easy as possible to complete without assistance (McColl et al., 2001).

On the day of testing, if a child’s questionnaire was incomplete, the questions were posed verbally to the children in Years 6 and 7, and to the parents/guardians of Years 1 and 2 children (if present, otherwise they were left incomplete). This was considered appropriate given that it has been shown that children are often able to provide more reliable information about themselves, regarding certain issues, than a close family member (Bell, 2007). Furthermore, in the case of children aged 11 years and over, survey research has been shown to be feasible with only limited modifications to questionnaires being required (Bell, 2007).

**Visual acuity**

Two charts are frequently used to measure visual acuity in a clinical and research setting: Snellen and Bailey-Lovie (logMAR) charts. Bailey-Lovie charts have many advantages over Snellen charts, including a logarithmic progression of optotype size from line to line, optotypes having equal legibility, same number of
optotypes on each line, and spacing between lines and optotypes being proportional to the size of the optotype (Bailey & Lovie, 1976; Williams, Moutray, & Jackson, 2008). The reliability and precision of Bailey-Lovie charts have resulted in them becoming the gold standard in clinical research (Kaiser, 2009). For this reason a three metre Bailey-Lovie logMAR letter chart was used to measure visual acuity in this study. In the small number of cases where the child was unable to read the letters on the chart, a three metre LEA symbol logMAR chart (Figure 4.2-1) with a matching card was used.

![Figure 4.2-1. LEA symbols logMAR chart](image)

In addition to chart selection, consideration of the measurement procedure to be used (termination rules and scoring methods) was also required, as the use of termination rules in acuity measurement has been shown to reduce unwanted variations in letter-by-letter scores (Carkeet, 2001). The measurement procedure used to assess visual acuity in this project was the same as that used by the Vision in Preschoolers study group (Vision in Preschoolers (VIP) Study Group, 2003); however, a Bailey-Lovie chart was used for the majority of testing rather than LEA symbols. The termination rule used in the VIP protocol has also been used in a number of other research studies (Brown & Lovie-Kitchin, 1993; Lovie-Kitchin & Brown, 2000). The procedure for measuring visual acuity in the current study is described in more detail in Appendix F – Testing protocol.
In this study, distance visual acuity was measured monocularly, right eye then left eye (unaided and with any habitual distance correction, where applicable). Vision impairment was categorised into four levels based on the child’s habitual visual acuity, that is with any existing spectacles (Robaei et al., 2005):

- None (≥6/12, logMAR 0.3 or better)
- Mild (<6/12 – 6/18, 0.32 – 0.5 logMAR)
- Moderate (6/24 – 6/48, 0.52 – 0.9 logMAR)
- Severe (≤6/60, 0.92 logMAR or worse)

**Cycloplegic retinoscopy**

Refractive error can be measured subjectively or objectively and with or without the use of cycloplegia. Differences between techniques include the time taken to administer the test, ease of the test, cost and potentially the accuracy of the results. A cycloplegic refraction eliminates the ability of the participant to accommodate (Funarunart et al., 2009) and cycloplegic refraction is considered the gold standard for measuring refractive error in children as opposed to non-cycloplegic techniques (Erdurmus et al., 2007).

Cyclopentolate is a commonly used cycloplegic agent with rapid onset and relatively short duration. The 1% concentration is recommended for infants and children younger than 12 years old and is also the gold standard upon which other cycloplegic agents are compared (Twelker & Mutti, 2001). Cyclopentolate 1% administered as a spray to the closed eyelid was used to achieve cycloplegia in the current study. The spray application has been shown to produce equivalent cycloplegia to eye drops, within a similar timeframe (Ismail & Rouse, 1994).

The preliminary study described in Chapter 3 was performed prior to the main study to investigate whether cycloplegic retinoscopy was the optimal method for measuring refractive error. The results of this preliminary study confirmed that cycloplegic retinoscopy was a repeatable and accurate method for measuring refractive error in school children as presented in Chapter 3. Thus cycloplegic retinoscopy was performed on both eyes with a streak retinoscope in a dimly lit room. The examiner was positioned 67 centimetres away from the child and the child was asked to look at a target three metres away. Positive and negative power
retinoscopy racks were used to determine the refractive power required to neutralise the streak movement along the principal meridians.

The refractive error range selected to define hyperopia, myopia and astigmatism in this study was based on the Sydney Myopia Study classifications, see Table 4.2-2 (Huynh et al., 2006; Ip, Robaei, et al., 2008; Ojaimi, Rose, Smith, et al., 2005). Spherical equivalent was used to quantify refractive error (sphere + ½ cylinder).

Table 4.2-2

Refractive error classification system used in the Sydney Myopia Study (Huynh et al., 2006; Ip, Robaei, et al., 2008; Ojaimi, Rose, Smith, et al., 2005)

<table>
<thead>
<tr>
<th>Classification of refractive error (Sydney Myopia Study)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hyperopia</td>
</tr>
<tr>
<td>≥0.50 dioptre</td>
</tr>
<tr>
<td>• Clinically significant hyperopia</td>
</tr>
<tr>
<td>• ≥2.00 dioptres</td>
</tr>
<tr>
<td>Myopia</td>
</tr>
<tr>
<td>≥0.50 dioptre</td>
</tr>
<tr>
<td>Emmetropia</td>
</tr>
<tr>
<td>-0.49 to +0.49 dioptres</td>
</tr>
<tr>
<td>Astigmatism</td>
</tr>
<tr>
<td>≥1.00 dioptre</td>
</tr>
<tr>
<td>Anisometropia</td>
</tr>
<tr>
<td>≥1.00 dioptre</td>
</tr>
</tbody>
</table>

*The classification for myopia, astigmatism and anisometropia were all considered clinically significant

In the current study, spherical refractive error was also classified as mild, moderate and high. The refractive error ranges in Table 4.2-3 were used to define the different levels of refractive error. These ranges are slightly different to those used in the Sydney Myopia study because it was considered that the cut-off for clinically significant hyperopia (2.00D or more) would be more appropriately classified as moderate rather than mild hyperopia. A child was considered myopic if at least one eye had myopia, hyperopic if at least one eye had hyperopia (in the absence of myopia in the other eye) and emmetropic if there was no myopia or hyperopia in either eye (Dandona et al., 2002).
Table 4.2-3
*Refractive error classification used in the current study*

<table>
<thead>
<tr>
<th>Classification of refractive error (current study)</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild myopia or hyperopia</td>
<td>0.50 – 1.75 dioptres</td>
</tr>
<tr>
<td>Moderate myopia or hyperopia</td>
<td>2.00 – 4.75 dioptres</td>
</tr>
<tr>
<td>High myopia or hyperopia</td>
<td>≥5.00 dioptres</td>
</tr>
<tr>
<td>Emmetropia</td>
<td>-0.49 to +0.49 dioptres</td>
</tr>
<tr>
<td>Astigmatism</td>
<td>≥1.00 dioptre</td>
</tr>
<tr>
<td>Anisometropia</td>
<td>≥1.00 dioptre</td>
</tr>
</tbody>
</table>

*Tests of binocular vision*

The following measures of binocular vision function were measured habitually, with the child either unaided or wearing their own spectacle correction if they had any. Habitual refraction was used for the binocular vision tests prior to refractive error determination to avoid the effect of cycloplegia on binocular function; a second day of testing to measure binocular vision after cycloplegic refraction was not possible with this study design.

STEREOACUITY

There is a wide range of commercially available tests for measuring stereopsis. The different stereotests vary in both the way in which disparity is created as well as the types of targets used (contour and or random dot).

Both contour targets (local process) and random dot (global process) are important in the measurement of stereopsis. Random dot stereograms have no monocular cues, and patients with a constant strabismus will fail to detect the stimulus (Cooper & Feldman, 1978). Contour stereograms however provide a better indication of the presence of peripheral stereopsis in strabismic patients with abnormal retinal correspondence (Fricke & Siderov, 1997).

The Randot stereotest (Figure 4.2-2) was selected for this study because it assesses stereopsis with both random dot targets (500 to 250 seconds of arc) and contour targets (400 to 20 seconds of arc), (Fricke & Siderov, 1997).
The Randot stereotest was held at 40 centimetres from the child in an upright position. The child wore polarising filters over their own refractive correction and was directed towards the graded contour circles test followed by the random dot test. Local and global stereopsis was measured in all children. The level of local stereopsis was the last group of circles that was selected correctly (seconds of arc). The level of global stereopsis was classified as ‘good’ (250 seconds of arc), ‘reduced’ (500 seconds of arc) or ‘no stereopsis’ depending on which shapes could be accurately discriminated in the random dot test. The local stereoacuity score and the category of normal, reduced and none for global stereopsis were used in the analysis.

 COVER TEST

The unilateral cover was used to detect the presence of a strabismus at distance and/or near. In the unilateral cover test, a fixation movement of the uncovered eye upon occlusion of the other eye is classified as strabismus (Calvin, Rupnow, & Grosvenor, 1996). The unilateral cover test is performed on both eyes, as in the case of a constant strabismus, no movement will be observed when the eye with the strabismus is covered and uncovered. The distance cover test was performed using a fixation target that was one line larger than the child’s best habitual visual acuity at a distance of 3 metres. For near, a 6/12 equivalent letter was presented at 40 centimetres.

 NEAR POINT OF CONVERGENCE

The near point of convergence (NPC) measures convergence amplitude. Different techniques have been used to measure NPC and vary in terms of the types...
of target used (accommodative target, penlight, penlight with red-green glasses), number of times the test is repeated, method (push-up or jump), point from where the NPC is measured (sight plane, corneal plane, bridge of nose) and method for determining the NPC break and recovery points (either subjectively or objectively), (Hayes, Cohen, Rouse, & DeLand, 1998).

For the purposes of this study, the NPC was measured with a 6/9 equivalent accommodative target following the standardised protocol used by the Convergence Insufficiency and Reading Study group (CIRS), (Hayes et al., 1998). This enabled the results to be directly compared with the normative values reported by the CIRS. The CIRS protocol used an accommodative target which was brought towards the participant. The break value was measured from the bridge of the nose to the point at which either diplopia was reported by the participant or a deviation of the eyes was observed by the examiner. The recovery point was the distance at which the child reported a return to single vision, or the examiner observed re-alignment of the eyes. The recovery measurement was recorded as the distance between the break and recovery point. An average of three measurements was used for the value of the NPC.

In addition to the mean NPC break and recovery points, a NPC break of greater than six centimetres and an NPC recovery point of greater than six centimetres beyond the break point were considered to represent reduced NPC for the purpose of this study (CITT Study Group, 2008; Hayes et al., 1998). This was based on a study which found that children with an NPC break of greater than six centimetres are more likely to be symptomatic and the recovery will usually be 3-4 centimetres greater than the break (Hayes et al., 1998).

PHORIA MEASUREMENT

The Howell-Dwyer phoria card measures horizontal heterophoria at distance and near and is administered in free-space, and requires the use of a loose prism. This test was selected because it has good repeatability (Wong, Fricke, & Dinardo, 2002) and the card design reduces peripheral fusional and stimulates accommodation (Junghans, Kiely, Crewther, & Crewther, 2002).

The distance Howell-Dwyer phoria card was placed at a distance of three metres and a six prism dioptre lens was held base down in front of the right eye to
dissociate the eyes. The distance Howell-Dwyer phoria card is capable of quantifying values from $10\Delta$ exophoria to $9\Delta$ esophoria; the near Howell phoria card was held at 33 centimetres from the child and quantifies values from $20\Delta$ exophoria to $21\Delta$ esophoria.

**Figure 4.2-3.** Distance and near Howell-Dwyer phoria cards

In addition to the mean distance and near phoria measurements, distance and near phoria measurements were grouped into the following three categories: esophoria (greater or equal to $2\Delta$), orthophoria (between $2\Delta$ esophoria and $2\Delta$ exophoria), and exophoria (greater or equal to $2\Delta$) which is the classification system used in the Sydney Myopia Study (Leone et al., 2010) and enabled comparison with previous studies.

**ACCOMMODATIVE CONVERGENCE TO ACCOMMODATION (AC/A) RATIO**

There are two main methods used to measure the AC/A ratio, the gradient and the calculated methods. The gradient method was selected because it better controls proximal convergence and the effect of accommodation lag compared to the calculated method (Jimenez, Perez, Garcia, & Gonzalez, 2004), resulting in a more accurate measure of the AC/A ratio.

The gradient method was performed by measuring the phoria using +/-2.00 dioptre lenses. The normal range of the AC/A ratio is between three and five: values above five are considered to denote excessive accommodative convergence and values under three indicate an insufficiency (von Noorden & Avilla, 1990).

**FUSIONAL VERGENCES**
Positive and negative fusional vergences can be measured using Risley prisms in the phoropter or with prism bars in free-space (Scheiman & Wick, 2002). The prism bar technique was used to measure fusional vergence range at distance and near in this study as the data collection was performed outside of a normal clinical environment on location in schools, so a non-instrument based technique was necessary. This technique is valid and repeatable and normative values are available for school-aged children (Antona, Barrio, Barra, Gonzalez, & Sanchez, 2008; Wesson, 1982).

Negative fusional vergence was measured first at distance. The child was directed to fixate on one letter above their best habitual visual acuity and a low powered base-in (BI) prism was introduced in front of the habitual correction. Increasing levels of prism power were introduced at a constant rate by the same examiner until the child reported diplopia or the eye was observed to be moving inwards (loss of fixation); lesser amounts of prism power were then re-introduced until the child reported single vision or alignment was observed again. This procedure was repeated three times and results recorded. If there was a discrepancy between objective and subjective break points, the measurement was repeated; the objective break point was used if the discrepancy between subjective and objective measures was also evident for the second measurement. Positive fusional vergence was then measured at distance with the same procedure as above, but using a base-out (BO) prism. This technique was repeated for negative and positive fusional vergence measurements at near, with a 6/12 (N6) letter used as the fixation target at a distance of 40 centimetres (Scheiman & Wick, 2002).

The values used in the analysis were the mean of the three readings for break and recovery. Typically, the blur point is used (not break point) as it represents the limit of fusional vergence on its own, however, the blur point can only be determined subjectively. Given the age group of the children in the study, break and recovery points were selected, as they can both be determined subjectively also.

A child was classified with a reduced fusional vergence result when the value was greater than one standard deviation below the expected value. Using the expected values from Scheiman and Wick (2002), the classification system applied in the analysis for reduced fusional vergence is given in Table 4.2-4.
Table 4.2-4

*Classification for reduced fusional vergence ranges*

<table>
<thead>
<tr>
<th></th>
<th>Break: &lt;4Δ</th>
<th>Recovery: &lt;5Δ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance PFV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance NFV</td>
<td>Break: &lt;4Δ</td>
<td>Recovery: &lt;2Δ</td>
</tr>
<tr>
<td>Near PFV</td>
<td>Break: &lt;15Δ</td>
<td>Recovery: &lt;10Δ</td>
</tr>
<tr>
<td>Near NFV</td>
<td>Break: &lt;7Δ</td>
<td>Recovery: &lt;3Δ</td>
</tr>
</tbody>
</table>

**ACCOMMODATIVE FACILITY**

The measurement of accommodative facility can vary depending on the target and instructions used. Plus and minus two dioptre flippers are most commonly used with a 6/9 (N5) target at 40 centimetres (Zellers, Alpert, & Rouse, 1984). Accommodative facility was only measured on children who had stereoacuity of 40 seconds or better to rule out the prospect of central suppression affecting facility measurements (McKenzie, Kerr, Rouse, & DeLand, 1987). The child was directed to view a line of 6/9 equivalent letters and asked to read the letters out aloud. The +2.00 dioptre lenses were introduced in front of the child’s eyes and the child was asked to continue reading as soon as the letters became clear. The -2.00 dioptre lenses were then flipped in front of the child’s eyes and again they were asked to continue reading the letters when they become clear. This was continued for 60 seconds, counting the number of cycles that took place. One cycle was considered to have occurred when both the +2.00D and -2.00 dioptre lenses had been flipped and reported as clear (Zellers et al., 1984). The mean accommodative facility using this method on adults was 7.7 ± 5.1 cycles per minute. Given that the expected values exhibit too wide a range to be meaningful, and were taken from an adult sample, a separate criterion was used to classify accommodative facility in the current study. This criterion was based on a study designed to evaluate accommodative facility in children (aged between 8 and 12 years) where reduced accommodative facility was
considered as a score of less than eight cycles per minute and a very reduced accommodative facility was considered to be less than three cycles per minute (McKenzie et al., 1987).

CONVERGENCE INSUFFICIENCY AND OTHER ACCOMMODATION AND/OR VERGENCE DISORDERS

Convergence insufficiency (CI) has been defined in various ways in different studies (Borsting, Rouse, & DeLand, 1999; Evans, 2000; Letourneau et al., 1979). In the current study, CI was classified according to the Convergence Insufficiency Treatment Trial (CITT), where the following three criteria need to be satisfied (CITT Study Group, 2008):

- Near exophoria at least $4\Delta$ more exophoric than distance phoria,
- Near point of convergence of $\geq 6$ centimetres (break) and
- Failing Sheard’s criterion (magnitude of exophoria is greater than half of the positive fusional vergence) or positive fusional vergence $\leq 15\Delta$ at near.

The integrative analysis approach was used to classify other accommodation and/or vergence disorders. With this approach, many clinical signs are considered to be indicators of an accommodation and/or vergence disorder, and the condition is diagnosed when the participant scores lower than expected across a number of these factors (Scheiman & Wick, 2002). These factors are listed in Table 4.2-5.

A child was classified as having convergence excess, divergence insufficiency and divergence excess when at least three of the corresponding factors listed in Table 4.2-5 were exhibited. Basic exophoria and basic esophoria were classified when the child had equal exophoria or esophoria at distance and near, as well as at least two of the final four corresponding factors listed in Table 4.2-5.
Table 4.2-5

Factors used for classification of different accommodation and/or vergence disorders

<table>
<thead>
<tr>
<th>Accommodation and/or vergence disorder</th>
<th>Factors</th>
</tr>
</thead>
</table>
| **Convergence excess**                 | • high AC/A (> 5Δ/D)  
   • near exophoria (≥ 2Δ)  
   • reduced accommodative facility (< 3 cycles/min)  
   • reduced negative fusional vergence at near (< 7Δ)  
   • poor recovery from base in prism at near (< 3Δ) |
| **Divergence excess**                  | • high AC/A (> 5Δ/D)  
   • exophoria greater at distance (distance exophoria ≥1Δ more exophoric than near phoria)  
   • low positive fusional vergence at distance (< 4Δ)  
   • low negative fusional vergence at near (< 7Δ)  
   • poor recovery to base out prism at distance (< 5Δ) |
| **Divergence insufficiency**           | • low AC/A (< 3Δ/D)  
   • exophoria greater at distance (distance esophoria ≥1Δ more esophoric than near phoria)  
   • low negative fusional vergence at distance (< 4Δ)  
   • poor recovery to base in prism at distance (< 2Δ) |
| **Basic exophoria**                    | • equal exophoria at distance and near (distance exophoria = near exophoria)  
   • normal AC/A (between 3 - 5Δ/D)  
   • low positive fusional vergence at distance (< 4Δ)  
   • low positive fusional vergence at near (< 15Δ)  
   • reduced accommodative facility (< 3 cycles/min) |
| **Basic esophoria**                    | • equal esophoria at distance and near (distance esophoria = near esophoria)  
   • normal AC/A (3 - 5Δ/D)  
   • low negative fusional vergence at distance (< 4Δ)  
   • low negative fusional vergence at near (< 7Δ)  
   • reduced accommodative facility (< 3 cycles/min) |
**Visual motor integration (VMI) skills**

The Beery-Buktenica Developmental Test of Visual Motor Integration (VMI), 5th edition (Pearson Assessments, 2004) was selected for use in this study as it is a widely used, validated and standardised test (Sortor & Kulp, 2003). The test requires the participant to copy 24 geometric shapes onto the recording sheet and assesses their ability to integrate visual information with motor movements. The shapes increase in complexity throughout the test and the test is stopped when the participant copies three shapes incorrectly in succession. The test was administered according to the instructions in the administration, scoring and teaching manual (Beery & Beery, 2006). The child’s raw score was calculated by counting the number of shapes that had been completed correctly. Raw scores were then converted to a standard score using the Beery VMI manual. The use of Beery VMI standard scores is strongly recommended, as this is a more reliable and valid measure than age equivalents of individual and group results (Beery & Beery, 2006). Beery VMI standard scores have a mean of 100 and a standard deviation of 15 and are based on raw score distributions. Standard scores were used in this study’s analysis.

**Rapid automatised naming (RAN)**

A number of tests of RAN are available and are most commonly used by neuropsychologists, educational psychologists and aphasiologists (Wiig, Zureich, & Chan, 2000). The main differences between the various tests are the number of items in each test sequence, as well as the type of item that is required to be named. Testing RAN requires the continuous naming of common objects, letters, colours and/or numbers (Blachman, 1984; Denckla, 1976; Garzia, Richman, Nicholson, & Gaines, 1990; Wiig et al., 2000).

The Developmental Eye Movement (DEM) test is one such test of RAN ability (Webber, Wood, Gole, & Brown, 2009). The DEM test consists of two vertical and one horizontal array of single digit numbers; each array of digits is a subtest of the DEM test (Ayton, Abel, Fricke, & McBrien, 2009; Webber et al., 2009). The subtests are scored by completion time and the number of errors made (Ayton et al., 2009). The DEM test isolates the effect of visual-verbal automaticity in its vertical subtests, that is, a measure or RAN (Garzia et al., 1990).

The DEM test was originally designed to assess horizontal saccadic eye movements in a simulated reading environment. However, one study investigating
the validity of the DEM test for measuring horizontal saccadic eye movements with an objective eye movement tracker found that the DEM test did not correlate well with saccadic eye movements, but was related to reading performance and visual processing and verbalisation speed (Ayton et al., 2009). Subsequently, only the vertical subtest results were analysed in the current study.

**Colour vision**

The Ishihara colour vision test was used to detect congenital red-green colour vision deficiency in this study. This test is comprised of a series of pseudoisochromatic test plates and is considered the gold standard for rapid identification of congenital red-green deficiencies (Dain, 2004). The test was held at 66 centimetres from the child, and the child wore their existing correction for near to perform the test.

Birch (1997) investigated the specificity and sensitivity of the Ishihara colour vision test depending on the different numbers of errors made and showed that a minimum of three errors on the transformation and vanishing design plates (first 16 plates) identified 98.7% of subjects with red-green colour deficiencies. The remaining 1.3% (deuteranomalous trichromats) who were classified as have normal colour vision were considered to have only a minimal colour vision deficiency (Birch, 1997). Therefore, a fail criterion of three or more errors on the 16 transformation and vanishing plates was used in this study.

### 4.2.4 PROCEDURE AND TIMELINE

Testing was performed in a classroom (or room of equivalent size) at each primary school with the assistance of experienced final year optometry students. All optometry students were trained and provided with a testing protocol (see Appendix F) prior to data collection. Instructions to the participants were followed as specified on the testing protocol; this ensured a consistent approach to testing between optometry students. Children were brought to the testing room in small groups (between two and five) and rotated through the various testing stations. The tests performed at each station are shown in Figure 4.2-4. It took 45 – 60 minutes for each child to complete testing stations one to four; station five (cycloplegic retinoscopy) was completed in a separate testing session (on the afternoon of the same day), so that the effect of the cycloplegia did not impact upon classroom activities. The optometry students did not assist with the retinoscopy. An example timeline for one
day of testing is included in Appendix G. The timeline varied between schools depending on the school’s own start and finish times, recess and lunch breaks.

*Figure 4.2-4. Vision tests performed at each testing station*

The results were recorded on an individual results sheet that the child took to each testing station (Appendix H).

In addition to the visual measures previously described, reading ability was also measured at Station 3 (see Figure 4.2-5). The reading results and analysis will be presented in Chapter 5.
4.2.5 ETHICAL CLEARANCE

The National Statement on Ethical Conduct in Human Research required that a committee application be completed for the main study as the research fell under the designated Chapter 4.7: Aboriginal and Torres Strait Islander Peoples; this committee application was accepted and approved by the Queensland University of Technology Human Research Ethics Committee on June 9, 2011. In addition, approval from the Queensland Government Department of Education and Training (Central Office) was obtained to conduct research within Queensland state education sites.

4.2.6 STATISTICAL ANALYSIS

Categorical variables were assessed with chi-square tests and continuous variables were assessed with $t$-tests. A $p$-value less than 0.05 was considered statistically significant.

4.3 RESULTS

4.3.1 PARTICIPANTS

Five hundred and ninety five (595) school children from selected Queensland primary schools consented to participate in this study. The number of children, organised by Indigenous status, age group, gender and region is presented in Table 4.3-1. Chi-square tests were performed to determine whether the proportion of Indigenous children differed by age group, gender or region.
Table 4.3-1

Number of children (%) grouped by Indigenous status, age group, gender and region. Chi-square tests for age group, gender and region are shown with significant results in bold text

<table>
<thead>
<tr>
<th></th>
<th>Total (n, %)</th>
<th>Indigenous (n, %)</th>
<th>Non-Indigenous (n, %)</th>
<th>Chi-square, p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Indigenous status</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>595 (100.0%)</td>
<td>181 (30.4%)</td>
<td>414 (69.6%)</td>
<td></td>
</tr>
<tr>
<td><strong>Age group</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Years 1 and 2</td>
<td>312 (52.4%)</td>
<td>105 (33.7%)</td>
<td>207 (66.3%)</td>
<td>$\chi^2 (1, n = 595)$ = 3.24, $p = 0.07$</td>
</tr>
<tr>
<td>Years 6 and 7</td>
<td>283 (47.6%)</td>
<td>76 (26.9%)</td>
<td>207 (73.1%)</td>
<td></td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>295 (49.6%)</td>
<td>90 (30.5%)</td>
<td>205 (69.5%)</td>
<td>$\chi^2 (1, n = 595)$ = 0.00, $p = 0.96$</td>
</tr>
<tr>
<td>Female</td>
<td>300 (50.4%)</td>
<td>91 (30.3%)</td>
<td>209 (69.7%)</td>
<td></td>
</tr>
<tr>
<td><strong>Region</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brisbane</td>
<td>237 (39.8%)</td>
<td>49 (20.7%)</td>
<td>188 (79.3%)</td>
<td>$\chi^2 (1, n = 595)$ = 17.67, $p &lt; 0.01$</td>
</tr>
<tr>
<td>Rural</td>
<td>358 (60.2%)</td>
<td>132 (36.9%)</td>
<td>226 (63.1%)</td>
<td></td>
</tr>
</tbody>
</table>

A larger proportion of Indigenous children were from rural Queensland. This difference is not unexpected, as the proportion of Indigenous and non-Indigenous people living in a particular location changes depending on the region. The proportion of Indigenous Queenslanders living in rural or remote Queensland is greater than the proportion of non-Indigenous Queenslanders living in the same areas; with 74% of Indigenous Queenslanders living in rural or remote Queensland compared with only 48% of non-Indigenous Queenslanders. Only 26% of the Queensland Indigenous population live in a major city, compared with 52% of non-
Indigenous people (Australian Bureau of Statistics, 2003). There were no other significant differences in demographics between Indigenous and non-Indigenous children.

4.3.2 OCULAR AND MEDICAL HISTORY

Questionnaires were returned for 572 children, which equates to a response rate of 96.1%. No questionnaires were returned blank. A summary of the responses to each question for Indigenous and non-Indigenous children is presented in Table 4.3-2. The completion rate varied between questions. This explains why there are different numbers of responses analysed for each question.
Table 4.3-2

Responses to parental questionnaire. Numbers in brackets represent the number of responses that were ‘yes’ over the total number of responses submitted for each question. Chi-square tests for each question by Indigenous status are shown with significant results in bold text.

<table>
<thead>
<tr>
<th></th>
<th>Indigenous</th>
<th>Non- Indigenous</th>
<th>Chi-square, ( p )-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ocular History</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage of children that had received a previous eye examination</td>
<td>15.0% (26/173)</td>
<td>29.3% (117/399)</td>
<td>( \chi^2 (1, n = 572) = 13.15 ) ( p &lt; 0.01 )</td>
</tr>
<tr>
<td>Percentage of children whose previous eye examination was at an optometry practice</td>
<td>41.7% (10/24)</td>
<td>79.8% (89/109)</td>
<td>( \chi^2 (1, n = 133) = 14.50 ) ( p &lt; 0.01 )</td>
</tr>
<tr>
<td>Percentage of children prescribed spectacles at a previous eye examination</td>
<td>11.5% (3/26)</td>
<td>26.5% (31/117)</td>
<td>( \chi^2 (1, n = 143) = 2.63 ) ( p = 0.11 )</td>
</tr>
<tr>
<td>Percentage of children with a positive family history of eye disease/conditions</td>
<td>24.6% (42/171)</td>
<td>27.2% (108/397)</td>
<td>( \chi^2 (1, n = 568) = 0.43 ) ( p = 0.51 )</td>
</tr>
<tr>
<td><strong>Medical History</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage of children with general health problems</td>
<td>15.2% (25/165)</td>
<td>13.2% (52/394)</td>
<td>( \chi^2 (1, n = 559) = 0.37 ) ( p = 0.54 )</td>
</tr>
<tr>
<td>Percentage of children with low birth weight</td>
<td>13.0% (21/161)</td>
<td>11.5% (45/390)</td>
<td>( \chi^2 (1, n = 551) = 0.25 ) ( p = 0.62 )</td>
</tr>
<tr>
<td>Percentage of children with hearing/ear problems</td>
<td>24.4% (40/164)</td>
<td>13.0% (51/392)</td>
<td>( \chi^2 (1, n = 556) = 10.94 ) ( p &lt; 0.01 )</td>
</tr>
<tr>
<td><strong>Near visual tasks performed at home</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage of children that spend at least one hour per day reading</td>
<td>28.4% (44/155)</td>
<td>32.7% (125/382)</td>
<td>( \chi^2 (1, n = 537) = 0.96 ) ( p = 0.33 )</td>
</tr>
<tr>
<td>Percentage of children that spend at least one hour per day on the computer</td>
<td>49.0% (74/151)</td>
<td>43.1% (165/383)</td>
<td>( \chi^2 (1, n = 534) = 1.54 ) ( p = 0.22 )</td>
</tr>
<tr>
<td><strong>Symptoms</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage of children that reported at least one visual symptom</td>
<td>37.7% (63/167)</td>
<td>42.1% (167/397)</td>
<td>( \chi^2 (1, n = 564) = 0.92 ) ( p = 0.34 )</td>
</tr>
</tbody>
</table>

Less Indigenous children had received a previous eye examination than reported by the non-Indigenous children, see Table 4.3-2. The odds of a child having...
received a previous eye examination were 2.15 times greater for non-Indigenous children compared with Indigenous children. Region of residence had no effect on whether a child had received a previous eye examination, $\chi^2(1, n = 572) = 0.38, p = 0.54$.

More non-Indigenous children had attended an optometry practice for their eye examination, while Indigenous children were more likely to have had their eye examination at their school, at a health centre or at the hospital compared with non-Indigenous children. There were also more ear and/or hearing problems reported in the Indigenous children. No other significant differences in responses existed between groups for the remaining questions in the questionnaire.

4.3.3 VISION IMPAIRMENT

The number of children with vision impairment by Indigenous status is presented in Table 4.3-3.
Table 4.3-3  
*Number of children (%) presenting with different levels of vision impairment (based on reduced habitual visual acuity), by Indigenous status*

<table>
<thead>
<tr>
<th>Visual acuity level</th>
<th>Total</th>
<th>Indigenous</th>
<th>Non-Indigenous</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥6/12 Both eyes</td>
<td>569 (96.0%)</td>
<td>176 (97.8%)</td>
<td>393 (95.2%)</td>
</tr>
<tr>
<td>At least one eye</td>
<td>585 (98.7%)</td>
<td>179 (99.4%)</td>
<td>406 (98.3%)</td>
</tr>
<tr>
<td>&lt;6/12 – 6/18</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Better eye</td>
<td>5 (0.8%)</td>
<td>1 (0.6%)</td>
<td>4 (1.0%)</td>
</tr>
<tr>
<td>Worse eye</td>
<td>14 (2.4%)</td>
<td>3 (1.7%)</td>
<td>11 (2.7%)</td>
</tr>
<tr>
<td>6/24 – 6/48</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Better eye</td>
<td>3 (0.5%)</td>
<td>0</td>
<td>3 (0.7%)</td>
</tr>
<tr>
<td>Worse eye</td>
<td>6 (1.0%)</td>
<td>0</td>
<td>6 (1.4%)</td>
</tr>
<tr>
<td>≤6/60</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Better eye</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Worse eye</td>
<td>4 (0.7%)</td>
<td>1 (0.6%)</td>
<td>3 (0.7%)</td>
</tr>
</tbody>
</table>

Only one Indigenous child presented with vision impairment in both eyes (<6/12 in better eye), compared with 7 non-Indigenous children; this was not a significant difference, $\chi^2 (1, n = 593) = 1.23, p = 0.27$. Interestingly, three Indigenous children had exceptionally good unaided visual acuity and were able to see the 6/3 acuity line in at least one eye, while no non-Indigenous children could see the 6/3 line unaided.
4.3.4 REFRACTIVE ERROR

The spread of the raw refractive error data by Indigenous status is presented in the following frequency distribution graph, see Figure 4.3-1. The $x$-axis represents the spherical refractive error in the eye with the highest refractive error, and the $y$-axis represents the percentage of children with this category of refractive error.

![Figure 4.3-1. Spread of spherical refractive error data by Indigenous status](image)

More non-Indigenous children had clinically significant refractive error, $\chi^2 (1, n = 549) = 4.23$, $p = 0.04$. Of the non-Indigenous children, 16.13% had clinically significant refractive error in at least one eye compared with 9.60% of Indigenous children.

The prevalence of the different refractive errors by Indigenous status is presented in Table 4.3-4. There was no difference in the prevalence of hyperopia, myopia, astigmatism or anisometropia between Indigenous and non-Indigenous children.
Table 4.3-4  
*Prevalence of refractive error (%) by Indigenous status*

<table>
<thead>
<tr>
<th></th>
<th>Indigenous</th>
<th>Non-Indigenous</th>
<th>Chi-square, $p$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hyperopia</strong></td>
<td>5.08%</td>
<td>8.06%</td>
<td>$\chi^2 (1, n = 549) = 1.61$</td>
</tr>
<tr>
<td>($\geq 2.00D$)</td>
<td></td>
<td></td>
<td>$p = 0.20$</td>
</tr>
<tr>
<td><strong>Myopia</strong></td>
<td>1.69%</td>
<td>4.03%</td>
<td>$\chi^2 (1, n = 549) = 2.07$</td>
</tr>
<tr>
<td>($\geq 0.50D$)</td>
<td></td>
<td></td>
<td>$p = 0.15$</td>
</tr>
<tr>
<td><strong>Astigmatism</strong></td>
<td>3.39%</td>
<td>1.89%</td>
<td>$\chi^2 (1, n = 549) = 1.18$</td>
</tr>
<tr>
<td>($\geq 1.00D$)</td>
<td></td>
<td></td>
<td>$p = 0.28$</td>
</tr>
<tr>
<td><strong>Anisometropia</strong></td>
<td>3.95%</td>
<td>5.65%</td>
<td>$\chi^2 (1, n = 537) = 0.96$</td>
</tr>
<tr>
<td>($\geq 1.00D$)</td>
<td></td>
<td></td>
<td>$p = 0.33$</td>
</tr>
</tbody>
</table>

The spread in spherical refractive errors was greatest amongst non-Indigenous children; none of the Indigenous children had moderate or high myopia or high hyperopia (see Figure 4.3-2).

*Figure 4.3-2. Range of spherical refractive errors for Indigenous and non-Indigenous children (%)*
Additional factors of age group and region were also assessed (in addition to Indigenous status) in relation to the different refractive errors. These additional factors were included firstly because refractive error can change depending on age (increase in myopia with age, and a reduction of hyperopia with age [emmetropisation]) and secondly, because metropolitan-rural differences have been shown in other studies with regards to the prevalence of refractive error (He et al., 2004; Rose, Morgan, Ip, et al., 2008). Step-wise regressions were performed and the final model for each refractive error is presented in Table 4.3-5.

Table 4.3-5
Contribution of different explanatory variables for each of the different refractive errors: hyperopia, myopia, astigmatism and anisometropia. Most parsimonious model from each step-wise regression is presented.

<table>
<thead>
<tr>
<th>Explanatory variable</th>
<th>β</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hyperopia (≥ 2.00D)</td>
<td>Age group</td>
<td>-0.05</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Adjusted R-squared: 0.01</td>
</tr>
<tr>
<td>Myopia (≥ 0.50D)</td>
<td>Region</td>
<td>-0.05</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Adjusted R-squared: 0.02</td>
</tr>
<tr>
<td>Astigmatism (≥ 1.00D)</td>
<td>None of the explanatory variables explained variation in astigmatism</td>
<td></td>
</tr>
<tr>
<td>Anisometropia (≥ 1.00D)</td>
<td>None of the explanatory variables explained variation in anisometropia</td>
<td></td>
</tr>
</tbody>
</table>

**Hyperopia**

Age group explained a negligible (1%) proportion of the variation in hyperopia. The prevalence of hyperopia decreased with age; 9.31% of children in the younger age group were hyperopic, compared with 4.63% of children in the older age group. Region and Indigenous status were not significant predictors of hyperopia.
Myopia

Region explained a negligible (2%) proportion of the variation in myopia. Myopia was less prevalent in rural areas. In the metropolitan Brisbane-based schools, 6.74% of children were myopic compared with 1.40% of children from rural schools. Indigenous status and age group were not significant predictors of myopia, nor was the interaction between either of these variables and region.

Neither Indigenous status, region or age group significantly predicted any variation in astigmatism or anisometropia.

Spectacle wear

The percentage of children with clinically significant refractive error in at least one eye who reported wearing spectacles is presented in Table 4.3-6. There was no significant difference in the proportion of Indigenous and non-Indigenous children who had spectacles, $\chi^2 (1, n = 75) = 0.08, p = 0.78$.

Table 4.3-6

<table>
<thead>
<tr>
<th></th>
<th>Indigenous</th>
<th>Non-Indigenous</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectacle use</td>
<td>17.64%</td>
<td>20.69%</td>
<td>20.00%</td>
</tr>
</tbody>
</table>

4.3.5 BINOCULAR VISION FUNCTION

Results from the binocular vision tests by Indigenous status are presented in Table 4.3-7. T-tests were used to determine if the difference in scores between Indigenous and non-Indigenous children was significant.
# Table 4.3-7

Mean scores obtained for binocular vision tests. Results from t-tests comparing the Indigenous and non-Indigenous groups are shown, and significant findings are in bold text.

<table>
<thead>
<tr>
<th>Test</th>
<th>Indigenous status</th>
<th>Mean ± sd</th>
<th>t-value, p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Near point of convergence (NPC)</td>
<td>Indigenous</td>
<td>Break: median = 6.66cm (2.3, 23.7) Recovery: median = 3.33cm (1.0, 16.7)</td>
<td>Break: $U(574) = 28938, p &lt; 0.01$ Recovery: $U(543) = 30697, p = 0.70$</td>
</tr>
<tr>
<td></td>
<td>Non-Indigenous</td>
<td>Break: median = 6.00cm (1.0, 25.3) Recovery: median = 3.33cm (1.0, 26.3)</td>
<td></td>
</tr>
<tr>
<td>Distance phoria</td>
<td>Indigenous</td>
<td>0Δ ± 2</td>
<td>$t(583) = 0.02, p = 0.981$</td>
</tr>
<tr>
<td></td>
<td>Non-Indigenous</td>
<td>0Δ ± 2</td>
<td></td>
</tr>
<tr>
<td>Near phoria</td>
<td>Indigenous</td>
<td>2Δ exophoria ± 3</td>
<td>$t(580) = 2.78, p = 0.01$</td>
</tr>
<tr>
<td></td>
<td>Non-Indigenous</td>
<td>1Δ exophoria ± 3</td>
<td></td>
</tr>
<tr>
<td>AC/A</td>
<td>Indigenous</td>
<td>2.20Δ/D ± 1.19</td>
<td>$t(550) = -0.07, p = 0.95$</td>
</tr>
<tr>
<td></td>
<td>Non-Indigenous</td>
<td>2.21Δ/D ± 1.57</td>
<td></td>
</tr>
<tr>
<td>Negative fusional vergence – distance</td>
<td>Indigenous</td>
<td>Break: 7.84Δ ± 4.49</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Non-Indigenous</td>
<td>Recovery: 3.49Δ ± 2.52</td>
<td>$t(534) = -1.37, p = 0.17$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Break: 8.50Δ ± 5.31</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Recovery: 3.98Δ ± 3.23</td>
<td>$t(541) = -1.69, p = 0.09$</td>
</tr>
<tr>
<td>Positive fusional vergence - distance</td>
<td>Indigenous</td>
<td>Break: 10.05Δ ± 7.61</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Non-Indigenous</td>
<td>Recovery: 4.90Δ ± 4.07</td>
<td>$t(532) = -1.58, p = 0.11$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Break: 11.24Δ ± 8.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Recovery: 5.73Δ ± 5.17</td>
<td>$t(527) = -1.77, p = 0.08$</td>
</tr>
<tr>
<td>Negative fusional vergence - near</td>
<td>Indigenous</td>
<td>Break: 7.45Δ ± 3.16</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Non-Indigenous</td>
<td>Recovery: 3.94Δ ± 2.39</td>
<td>$t(538) = -2.29, p = 0.02$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Break: 8.35Δ ± 4.43</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Recovery: 4.58Δ ± 2.94</td>
<td>$t(536) = -2.41, p = 0.02$</td>
</tr>
<tr>
<td>Positive fusional vergence - near</td>
<td>Indigenous</td>
<td>Break: 10.41Δ ± 6.45</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Non-Indigenous</td>
<td>Recovery: 5.95Δ ± 4.89</td>
<td>$t(536) = -3.99, p &lt; 0.01$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Break: 13.12Δ ± 7.35</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Recovery: 8.23Δ ± 5.65</td>
<td>$t(532) = -4.38, p &lt; 0.01$</td>
</tr>
<tr>
<td>Accommodative facility</td>
<td>Indigenous</td>
<td>5.75 cpm ± 2.48</td>
<td>$t(540) = 2.60, p = 0.01$</td>
</tr>
<tr>
<td></td>
<td>Non-Indigenous</td>
<td>5.10 cpm ± 2.73</td>
<td></td>
</tr>
</tbody>
</table>

Chapter 4: Visual profile of Queensland Indigenous children
**Near point of convergence (NPC)**

The mean NPC break point was significantly more remote (poorer performance) in Indigenous children, see Table 4.3-7, however, as this difference was less than one centimetre, it was not considered clinically significant (Anderson, Stuebing, Fern, & Manny, 2011). A box plot showing the spread of the NPC break point results is presented in Appendix I.

There was no difference in the mean recovery distance between groups. When reduced NPC was classified as a break distance greater than 6cm (CITT Study Group, 2008; Hayes et al., 1998), a greater percentage of Indigenous children had a reduced NPC, $\chi^2 (1, n = 574) = 8.54, p < 0.01$; 55.8% of Indigenous children met this criteria, compared with 42.5% of non-Indigenous children.

**Heterophorias**

The difference in mean distance horizontal heterophoria (phoria) between Indigenous and non-Indigenous children was not statistically significant, see Table 4.3-7. While the difference in mean near heterophoria was statistically significant (Table 4.3-7); this difference was not clinically significant; a difference of 2∆ or more is considered clinically significant (Anderson et al., 2011). Appendix I shows the spread of near heterophoria results by Indigenous status in a box plot. The outlier represents one non-Indigenous child with a very high esophoria at near.

The percentage of Indigenous and non-Indigenous children with different levels of distance and near heterophoria is presented in Figure 4.3-3 and Figure 4.3-4 respectively. There was no difference in the percentage of Indigenous and non-Indigenous children with a distance esophoria ($\chi^2 [1, n = 585] = 0.01, p = 0.96$) or a distance exophoria ($\chi^2 [1, n = 585] = 0.80, p = 0.37$). At near, a greater percentage of Indigenous children had exophoria, $\chi^2 (1, n = 582) = 8.45, p = 0.01$, and a greater percentage of non-Indigenous children had esophoria, $\chi^2 (1, n = 582) = 8.48, p = 0.01$. The clinical significance of these findings, however, are limited, given that a cut-off of 2∆ was used to define esophoria and exophoria and in many cases, an exophoria of this magnitude at near is considered a normal result.

A better method for understanding the clinical significance of heterophoria, is to incorporate the phoria measurement into a classification system for binocular vision disorders. This approach has also been adopted at the end of this section.
Figure 4.3-3. Percentage of Indigenous and non-Indigenous children with different levels of distance heterophoria.
No significant difference in the mean AC/A ratios was found between Indigenous and non-Indigenous children as shown in Table 4.3-7. Similarly, the proportion of children with AC/A ratios that had high or low AC/A ratios did not differ by Indigenous status, $\chi^2 (2, n = 561) = 4.42$, $p = 0.11$.

**Fusional vergences**

The mean positive and negative fusional vergences at near (break and recovery) were lower for Indigenous children, see Table 4.3-7. Box plots for all four fusional vergence measures are presented in Appendix I.

More Indigenous children had lower positive fusional vergences at near, see Figure 4.3-4, (break: $\chi^2 (1, n = 540) = 9.92$, $p < 0.01$; recovery: $\chi^2 (1, n = 534) = 18.50$, $p < 0.01$).
The cut-off values used to classify fusional vergences have been presented previously in Table 4.2-4. The percentage of children with reduced negative fusional vergences according to these cut-offs was not significantly different between Indigenous and non-Indigenous children, (break: $\chi^2 (1, n = 540) = 3.20, p = 0.07$; recovery: $\chi^2 (1, n = 538) = 1.03, p = 0.32$), see Figure 4.3-6.

Figure 4.3-6. Percentage of children with a reduced positive fusional vergence result (at near)
Figure 4.3-6. Percentage of children with a reduced negative fusional (at near)

The mean positive and negative fusional vergences at distance for Indigenous and non-Indigenous children were similar (see Table 4.3-7), as were the proportion of children with reduced fusional vergences at distance.

Accommodative facility

Indigenous children had significantly higher levels of accommodative facility, see Table 4.3-7; although this difference was less than one cycle/minute and therefore not considered clinically significant; a clinically significant difference would be considered at least one cycle/minute. The percentage of Indigenous and non-Indigenous children with normal, reduced and very reduced accommodative facility is presented in

Table 4.3-8. There was no difference in the percentage of Indigenous and non-Indigenous children between the two groups, $\chi^2 (2, n = 323) = 4.42, p = 0.11$. 
Table 4.3-8

Percentage of Indigenous and non-Indigenous children with normal, reduced and very reduced accommodative facility

<table>
<thead>
<tr>
<th></th>
<th>Indigenous</th>
<th>Non-Indigenous</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal accommodative facility (≥8 cycles/minute)</td>
<td>16.04%</td>
<td>17.97%</td>
</tr>
<tr>
<td>Reduced accommodative facility (3 – 7 cycles/minute)</td>
<td>70.75%</td>
<td>59.91%</td>
</tr>
<tr>
<td>Very reduced accommodative facility (&lt;3 cycles/minute)</td>
<td>13.21%</td>
<td>22.12%</td>
</tr>
</tbody>
</table>

The results in Table 4.3-9 indicate that the classification criteria employed by McKenzie et al. (1987) for reduced accommodative facility in children aged between 8 and 12 years, which was adopted in the current study, may not be optimal for determining reduced accommodative facility in this cohort. Only a small percentage of children (Indigenous: 16.04%, non-Indigenous: 17.97%) were classified as normal according to this criteria.

Accommodation and/or vergence disorders

The percentage of children with different accommodation and/or vergence disorders by Indigenous status is presented in Table 4.3-10. Convergence insufficiency (CI) was the most prevalent accommodation and/or vergence disorder in both groups, with a significantly higher percentage of Indigenous children having this condition. A higher percentage of non-Indigenous children had divergence insufficiency or basic esophoria, while there were no significant differences by Indigenous status for any of the other conditions. CI is the only accommodation and/or vergence disorder that was further analysed, given that it was most prevalent in both groups and twice as common in Indigenous children compared with non-Indigenous children. The remaining accommodation and/or vergence disorders were not considered because only small numbers of children were classified as having these conditions.
Table 4.3-10

Percentage of Indigenous and non-Indigenous children with accommodation and/or vergence disorders; significant differences are in bold text

<table>
<thead>
<tr>
<th>Accommodation and/or vergence disorder</th>
<th>Indigenous</th>
<th>Non-Indigenous</th>
<th>Chi-square, p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convergence insufficiency</td>
<td>10.3%</td>
<td>5.2%</td>
<td>$\chi^2 (1, n = 484) = 4.15,$ $p = 0.04$</td>
</tr>
<tr>
<td>Convergence excess</td>
<td>5.4%</td>
<td>5.4%</td>
<td>$\chi^2 (1, n = 520) = 0.00,$ $p = 0.99$</td>
</tr>
<tr>
<td>Divergence insufficiency</td>
<td>1.7%</td>
<td>4.7%</td>
<td>$\chi^2 (1, n = 512) = 3.96,$ $p &lt; 0.05$</td>
</tr>
<tr>
<td>Divergence excess</td>
<td>4.8%</td>
<td>8.8%</td>
<td>$\chi^2 (1, n = 510) = 2.36,$ $p = 0.13$</td>
</tr>
<tr>
<td>Basic exophoria</td>
<td>2.1%</td>
<td>4.1%</td>
<td>$\chi^2 (1, n = 514) = 1.34,$ $p = 0.25$</td>
</tr>
<tr>
<td>Basic esophoria</td>
<td>0.7%</td>
<td>4.1%</td>
<td>$\chi^2 (1, n = 514) = 4.09,$ $p = 0.04$</td>
</tr>
</tbody>
</table>

The percentage of children meeting each clinical criterion for CI by Indigenous status is presented in Table 4.3-11. Chi-square results are shown, with significant findings in bold text. Significantly more Indigenous children had reduced NPC and/or a reduced positive fusional vergence compared with non-Indigenous children.
Table 4.3-11

Percentage of children with the different clinical criteria used for classification of convergence insufficiency, by Indigenous status. Chi-square results are shown with significant findings in bold text

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Indigenous</th>
<th>Non-Indigenous</th>
<th>Chi-square, p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physiological exophoria (≥ 4Δ)</td>
<td>17.42%</td>
<td>11.88%</td>
<td>χ² (1, n = 582) = 3.23, p = 0.07</td>
</tr>
<tr>
<td>Reduced NPC (≥ 6cm)</td>
<td>69.38%</td>
<td>53.53%</td>
<td>χ² (1, n = 528) = 11.52, p &lt; 0.01</td>
</tr>
<tr>
<td>Reduced positive fusional vergence (fails Sheard’s criteria or ≤ 15Δ)</td>
<td>81.70%</td>
<td>67.79%</td>
<td>χ² (1, n = 538) = 10.45, p &lt; 0.01</td>
</tr>
</tbody>
</table>

**Stereopsis**

The percentage of children with good (250 seconds of arc), reduced (500 seconds of arc) and no global stereopsis is presented in Table 4.3-12. There was no difference in the percentage of Indigenous and non-Indigenous children with reduced or no global stereopsis test, χ² (1, n = 589) = 0.32, p = 0.57. The local stereoacuity results were also similar between groups, U (593) = 35983.5, p = 0.43.
### Table 4.3-12

*Global and local stereopsis results by Indigenous status*

<table>
<thead>
<tr>
<th>Global stereopsis (% of children)</th>
<th>Indigenous</th>
<th>Non-Indigenous</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good</td>
<td>96.63%</td>
<td>94.89%</td>
</tr>
<tr>
<td>Reduced</td>
<td>1.69%</td>
<td>2.43%</td>
</tr>
<tr>
<td>None</td>
<td>1.69%</td>
<td>2.68%</td>
</tr>
</tbody>
</table>

| Local stereopsis (median score [min, max]) | 40" (20, 200) | 40" (20, 400) |

**Strabismus**

None of the Indigenous children had strabismus. While at distance, 2.7% of non-Indigenous children had strabismus, \( \chi^2 (1, n = 576) = 4.77, p = 0.03 \), and at near, 3.0% of non-Indigenous children had strabismus, \( \chi^2 (1, n = 569) = 5.01, p = 0.03 \).

#### 4.3.6 VISUAL MOTOR INTEGRATION (VMI)

The mean VMI score (as a standardised score) was significantly lower in Indigenous children (Indigenous: 92.69 ± 13.86, non-Indigenous: 98.37 ± 14.76; \( t(586) = -4.37, p < 0.01 \)). The distribution of VMI standardised scores by Indigenous status is presented as a box plot in Appendix I.

The mean standardised score is 100 with a standard deviation of 15. A higher percentage of Indigenous children had a VMI standardised score that was more than one standard deviation below the mean (that is a score of 84 or less), \( \chi^2 (1, n = 588) = 10.75, p < 0.01; 28.09\% \) of Indigenous children had a VMI standard score of 84 or less, compared with 16.34\% of non-Indigenous children.

#### 4.3.7 RAPID AUTOMATISED NAMING (RAN)

The mean time taken to complete the two vertical subtests on the Developmental Eye Movement test for Indigenous and non-Indigenous children is presented in Table 4.3-13.
### Table 4.3-13

*Time taken to complete vertical subtest of DEM (raw score), by Indigenous status*

<table>
<thead>
<tr>
<th>Years 1 and 2</th>
<th>Indigenous</th>
<th>Non-Indigenous</th>
<th>t-value, p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>86.17 ± 36.15</td>
<td>79.90 ± 32.69</td>
<td>t(299) = 1.52, p = 0.13</td>
</tr>
<tr>
<td>Years 6 and 7</td>
<td>47.66 ± 18.40</td>
<td>44.03 ± 13.81</td>
<td>t(275) = 1.76, p = 0.08</td>
</tr>
</tbody>
</table>

Higher raw scores represent a longer time taken to complete the vertical subtest of the DEM; therefore, higher raw scores indicated a lower RAN ability. The spread of the raw scores are presented in Appendix I as box plots by age group and by Indigenous status. One Indigenous child from the younger age group and the older age group took a very long time to complete the DEM vertical subtest (300 seconds and 141 seconds, respectively); two outliers represent these results.

A significantly higher percentage of Indigenous children had a DEM raw vertical score that was more than one standard deviation below the expected mean, $\chi^2 (1, n = 578) = 4.04, p = 0.04$; 67.43% of Indigenous children had a raw vertical score lower than one standard deviation below the expected mean, compared with 58.56% of non-Indigenous children.

Given that RAN has an auditory-verbal language component, the association between reduced RAN and hearing loss (self-reported/parent-reported) was investigated, however, reduced RAN was not associated with hearing loss in Indigenous children, $t(156) = 0.37, p = 0.71$ (or in non-Indigenous children, $t(383) = 1.65, p = 0.10$).

#### 4.3.8 COLOUR VISION

There was no difference in the prevalence of colour vision deficiency (CVD) between Indigenous and non-Indigenous girls. Two girls had a CVD (one Indigenous and one non-Indigenous). There was also no difference in CVD between Indigenous and non-Indigenous boys; 4.5% of Indigenous boys had a CVD compared with 4.4% of non-Indigenous boys, $\chi^2 (1, n = 293) = 0.01, p = 0.98$.

Interestingly, there was a difference in the prevalence of CVD by region, for Indigenous boys, with 16.7% of Indigenous boys in Brisbane having a CVD compared with 1.4% of Indigenous boys living in rural areas, $\chi^2 (1, n = 89) = 7.79, p$
There was no rural difference for non-Indigenous boys, or Indigenous and non-Indigenous girls.

4.4 DISCUSSION

The current study sought to characterise the visual profile of Queensland Indigenous children compared with non-Indigenous children. Refractive error and strabismus were less common in the Indigenous children, however, reduced near point of convergence, reduced positive fusional vergence and near exophoria were more common which subsequently resulted in CI being almost twice as common compared with non-Indigenous children. VMI scores were also lower in Indigenous children and more Indigenous children scored more than one standard deviation below the expected score in RAN (vertical subtest of DEM test). Furthermore, Indigenous children were less likely to have had an eye examination in the past.

4.4.1 PREVIOUS EYE EXAMINATIONS AND OTHER MEDICAL HISTORY

The current study showed that only 15% of Indigenous children had previously had an eye examination, compared with almost 30% of non-Indigenous children. It has previously been shown that existing eye care services are not meeting the needs of many Queensland Indigenous communities (Wildsoet & Wood, 1996); with the availability of culturally appropriate eye care services in both metropolitan and rural communities being insufficient. In their study, it was reported that only 13% of Indigenous teenagers (aged 15 – 19 years) who had no history of previous eye problems, had received an eye examination in the past five years. The authors concluded that, in addition to improved access to appropriate services, better education about eye health issues, including the fact that eye examinations involved no direct cost to the patient, was required (Wildsoet & Wood, 1996).

Wildsoet and Wood’s (1996) study also showed that in the event of an eye problem developing, Indigenous people were most likely to consult a GP, followed by Indigenous health clinics, and then optometrists. Similar findings were shown in the current study, where despite the fact that the Indigenous and non-Indigenous children were recruited from comparable geographic regions, far more non-Indigenous children had attended an optometry practice for an eye examination (80% compared with 42%), while Indigenous children had received more eye tests at medical centres, hospitals or schools. This may reflect Indigenous people’s
preference to visit health centres or schools where mediators or other staff from their own communities may be available (Wildsoet & Wood, 1996). For optometry as a profession, preference for this medical model makes the challenge of providing accessible and culturally sensitive eye care to Indigenous communities harder, but will potentially result in improved uptake and support of the service.

There was no difference in the percentage of children with a self-reported history of general health problems between groups, despite reports that Indigenous children experience poorer levels of health overall (Blair et al., 2005). However, hearing and ear problems (self-reported) were common in Indigenous children, with almost one quarter reporting these problems in the past. Otitis media (a middle ear disease) is very common in this population, with over one third of children from some communities having perforated ear drums as a result of this condition (Morris, 1998). This is believed to be due to the greater density and variety of respiratory pathogens that cause otitis media in rural Aboriginal children (Leach, Boswell, Asche, Nienhuys, & Mathews, 1994).

It is possible that hearing loss could potentially affect the development of RAN ability due to the auditory-verbal language component associated with this skill. This was explored in this study through analysis of hearing loss against RAN skills, but no relationship was found. It is not anticipated that poor hearing or ear problems would be associated with any of the other visual parameters measured in this study.

### 4.4.2 VISION IMPAIRMENT

The majority of children in the current study (96%) did not have vision impairment (as determined by a visual acuity of less than 6/12) in either eye; this is in agreement with the findings of the Sydney Myopia Study on children of similar age groups, where 96% of children also had no vision impairment. The Sydney Myopia Study, however, did not report on the prevalence of vision impairment by Indigenous status.

Less Indigenous children had vision impairment in both eyes (0.6%) compared with non-Indigenous children (1.7%) in the current study. Similar results were reported in the National Indigenous Eye Health Survey (NIEHS), which included 1694 Indigenous children aged between 5 and 15 years. Their study showed that
1.4% of Indigenous children had bilateral vision impairment compared with 6.4% in the general population (Taylor, Xie, et al., 2010).

The only other study that has reported on the level of visual acuity in Indigenous children was performed in seven communities across South Australia, and included 1514 Indigenous people of all ages (Stocks et al., 1997). In their study, vision impairment was classified as a visual acuity of less 6/18 and only three Indigenous people under the age of 50 years had this level of reduced acuity in one or both eyes and no vision impairment across the age range of 0 – 19 years. The accuracy of the results relating to the younger age groups in their study however is questionable, as the authors reported that all of the children aged between 0 – 1 years had 6/6 vision or better in both eyes which was measured with a visual acuity chart. This finding seems implausible given firstly, the difficulty of measuring visual acuity in this age group with a standard chart, and secondly, it is unlikely that the visual system of children this young has matured sufficiently to resolve this level of detail. The mean visual acuity in a large sample of two month old children was two cycles/degree (≈ 6/90) and in one year old children was eleven cycles/degree (≈ 6/18), (Rios Salomao & Fix Ventura, 1995).

Three Indigenous children in the current study also had a high level of unaided visual acuity (6/3); this finding has been shown in one other study, where more Australian Indigenous adults had high levels of unaided visual acuity (6/2.4) compared with adults of European descent (Taylor, 1981).

The conclusions made regarding the visual acuity findings in Indigenous children in the current study are based on children living in Brisbane and rural areas. These findings may not be representative of Indigenous children living in remote areas of Australia, who have higher rates of the vision-threatening condition, trachoma (Taylor, Fox, et al., 2010). This may explain why there were few Indigenous children in the current study with bilateral vision impairment compared with the NIEHS, which was a larger scale study, conducted in metropolitan, rural and remote to very remote communities in Australia.

4.4.3 REFRACTIVE ERROR

There was less clinically significant refractive error in Indigenous children (9.6%), compared with non-Indigenous children (16.1%). The NIEHS reported an
overall prevalence of refractive error of 8.7% in Indigenous children, which is comparable with these findings. In their study, refractive error was only measured in children whose unaided visual acuity was less than 6/12 and could be improved with pinhole – this method has the potential to miss low levels of hyperopia and astigmatism. Indeed, the current study is the first to measure refractive error in a large group of Indigenous children (with or without corresponding visual acuity loss) under cycloplegic conditions and found less refractive error overall compared with non-Indigenous children.

Twice as many Indigenous children in the current study who had refractive error had spectacles (17.6%) compared with those identified as having refractive error in the NIEHS (8%). This may be due to the children in the current study having better access of eye care services due to their relatively closer proximity to metropolitan centres. In the NIEHS, a number of remote communities were included; in these communities only limited optometric services and subsequent dispensing of spectacles were available.

Spectacle use by non-Indigenous children with refractive error in the current study was also low (20.7%). In the Sydney Myopia Study, 54.7% of twelve year old children with clinically significant refractive error in at least one eye wore spectacles (Robaei, Kifley, Rose, & Mitchell, 2006). Differences in sample demographics between the two studies would explain this disparity in spectacle use. All children from the current study attended schools in low socio-economic areas, whereas the Sydney Myopia Study included children from high, middle and low socioeconomic backgrounds (Ojaimi, Rose, Smith, et al., 2005).

The prevalence of refractive error has been shown to vary dependent on ethnic backgrounds in a number of studies. The Refractive Error Study in Children (RESC) was a multi-country study that measured the prevalence of refractive error in children aged between 5 and 15 years of different ethnic origins (Negrel et al., 2000). The prevalence of hyperopia, myopia and astigmatism varied significantly in the RESC between ethnic groups (Dandona et al., 2002; He et al., 2009; Murthy et al., 2002; Naidoo et al., 2003). Other studies have also reported a difference in the prevalence of different refractive errors depending on ethnicity (Fuller, Baxter, Harun, & Levy, 1995; Garber, 1981; Ip, Robaei, et al., 2008; Rose, Morgan, Ip, et al., 2008).
In addition to Indigenous status, other factors that were associated with refractive error in the current study were age group and region. The prevalence of hyperopia has been shown to reduce with age also in other studies (Ip, Robaei, et al., 2008; Zhao et al., 2000). This reduction is believed to be as a result of the process of emmetropisation (Ingram, Arnold, Dally, & Lucas, 1991).

The metropolitan-rural difference in myopia prevalence (in children of same ethnicity) has also been reported previously, with myopia being generally less prevalent in rural areas (He et al., 2009; Ip, Rose, et al., 2008). One explanation for the lower rate of myopia in rural regions is that children living in these areas may have more outdoor space and better accessibility to outdoor activities which is believed to be a protective factor for myopia (He et al., 2009; Jones-Jordan et al., 2011; Rose, Morgan, Ip, et al., 2008). In the current study, a greater percentage of Indigenous children lived in rural regions, however, there was no significant interaction between region and Indigenous status in terms of myopia prevalence.

In summary, the current study is the first of its kind to report on the prevalence of refractive error (hyperopia, myopia, astigmatism and anisometropia) in Queensland Indigenous children. This knowledge is important because it suggests that many Indigenous children will not have reduced visual acuity (as a result of uncorrected refractive error) which is the main test performed in many vision screenings. Eye care practitioners need to tailor their examination and/or screenings to target conditions that are most prevalent in Indigenous children, such as CI, which is discussed in the subsequent section.

4.4.4 BINOCULAR VISION FUNCTION

Strabismus

Strabismus is the only binocular vision condition in Australian Indigenous children that has been investigated previously. In one study from the Northern Territory, school screening results revealed that less than one percent of Indigenous children had strabismus (Paterson et al., 1998). However, the technique used to detect strabismus and the types of strabismus found were not reported. Furthermore, the accuracy of the findings is questionable, given that the testing was performed by nurses and Aboriginal Health Workers rather than by trained vision professionals. It has been previously shown that nurses’ ability to perform a cover test procedure and detect strabismus consistently is debatable (MacFarlane, Fitzgerald, & Stark, 1987).
Nevertheless, a low prevalence of strabismus was reported in Paterson et al.’s (1998) study, which is similar to the findings of the current study.

Two other studies have also reported a low prevalence of strabismus in Indigenous Australians. In the National Trachoma and Eye Health Project, the prevalence of esotropia and exotropia in Indigenous adults was 0.2% and 0.5%, respectively (Taylor, 1980), while in a study on Indigenous adults from the Western Desert region, of the 804 people assessed, there were no cases of convergent strabismus; the prevalence of divergent strabismus was not, however, reported in their study (Mann & Rountree, 1968).

The prevalence of strabismus in non-Indigenous children (3.0%) in the current study was significantly greater than that of Indigenous children (no strabismus). The results for the non-Indigenous group compares closely to those of the Sydney Myopia Study, where 2.8% of children had strabismus (Robaei, Rose, et al., 2006). Other studies have also found differences in the prevalence of strabismus depending on ethnic background, with esotropia being less common in children of a non-white ethnic background (Cotter et al., 2011; Robaei, Huynh, Kifley, Gole, & Mitchell, 2007).

Strabismus is the only binocular vision condition that has been investigated previously in Australian Indigenous children. The prevalence of accommodation and/or vergence disorders has not been reported in this group; nor have any of the individual visual parameters measured for the assessment of these conditions. In the current study, a number of measures of binocular vision were taken, including horizontal heterophorias, fusional vergence range and near point of convergence. In addition, it was possible to determine the prevalence of a number of accommodation and/or vergence disorders, based on standardised classification definitions.

**Convergence insufficiency (CI)**

In the current study, 10.3% of Indigenous children had CI compared with 5.2% of non-Indigenous children. This difference was statistically significant and is important due to the association between accommodation and/or vergence disorders and reduced reading ability, given that Indigenous children score lower in tests of reading ability (Collins, 1999). The prevalence of CI varies significantly in the literature, ranging from 1.8% to 83% (Letourneau & Ducic, 1988). Differences in
the definition of CI, criteria used for diagnosis, methods of measurement and differences in characteristics of the population are all possible reasons for the different findings between studies (Bennett, Blondin, & Ruskiewicz, 1982; Letourneau & Ducic, 1988; Rouse, Hyman, Hussein, & Solan, 1998; Shin et al., 2009).

The current study is the only study to report differences in CI based on ethnicity. However, only one other study using the same classification system compared CI findings between children of different ethnic backgrounds. In that study, the prevalence of CI was between 4 – 5% in white, black, Hispanic and Asian-Pacific children (Rouse et al., 1998). The prevalence of CI in that study agrees with the findings for non-Indigenous children in the current study. Yet the prevalence of CI in Indigenous children is significantly greater. Given this finding, the individual measures used for the classification of CI will be discussed, in order to determine whether one specific measure is driving the outcome.

**Physiological horizontal heterophoria**

There was no difference in the prevalence of a physiological exophoria (a near phoria that is at least four prism dioptres more exophoric than the distance phoria) greater or equal to four prism dioptres between Indigenous and non-Indigenous children, which was one of the criteria used for the CI classification. However, the mean near horizontal phoria (irrespective of the magnitude of the distance phoria) was more exophoric in Indigenous children, and more had a high exophoria at near. This indicates that although Indigenous children were more exophoric at near, the shift in phoria from distance to near (physiological exophoria) was similar between the two groups.

The Sydney Myopia Study is the only Australian study that has compared phoria measurements between ethnic groups (Leone et al., 2010). Their results showed that East Asian children were more likely to be exophoric, compared with Caucasian children. East Asian children have increased intercanthal distances which have been associated with exophoria (AlAnazi, AlAnazi, & Osuagwu, 2013; Quant & Woo, 1993). A similar explanation may exist for Indigenous children, however, intercanthal distance was not measured in the current study, and has not been investigated in other studies either. Refractive error was also associated with near phoria in the Sydney Myopia Study, with esophoria being associated with hyperopia.
and exophoria with myopia. This relationship was not demonstrated in the current study as there was more exophoria amongst Indigenous children, yet less myopia.

**Near point of convergence (NPC)**

A NPC break point greater than six centimetres was used as one of the criterion for CI in the CITT and in the current study (CITT Study Group, 2008). A greater percentage of Indigenous children (55.8%) had a reduced NPC according to this classification compared with non-Indigenous children (42.5%), these differences were statistically significant. Only one other study has compared NPC results between ethnic groups and found no significant difference between white and Native Americans (Maples & Hoenes, 2007). However, Maples and Hoenes (2007) found only 10% of children had reduced NPC using the same classification (greater than 6 centimetres). The small number of children with reduced NPC in their study is likely to be due to differences in methodology, as unlike the current study, they used a non-accommodative target to measure NPC. Target type, as well as target size, measuring point and speed of target have all been shown to affect NPC results (Hayes et al., 1998). Our finding that a high percentage of both the Indigenous and non-Indigenous children had reduced NPC using the same classification as the CITT study and Maples and Hoenes’ study raises some question about the appropriateness of these cut-off levels. It would be useful to investigate whether this is an appropriate level for this group in future studies. This could be achieved by determining what percentage of children with reduced NPC are either symptomatic or show other signs of CI, such as reduced positive fusional vergences and/or larger exophoria at near.

Differences in methodology and definitions used to classify reduced NPC mean that direct comparisons between studies are difficult. Nevertheless, a reduced NPC was more prevalent in Indigenous children in the current study. It is important therefore to determine whether the reduced NPC is impacting on this group functionally, such as causing symptoms that have been associated with CI, or determining whether there is a relationship between this parameter and reading skills. This relationship between CI and reading ability is further examined in the following chapter (Chapter 5). Using a standardised symptom survey would be another useful method to determine whether a greater number of symptoms are reported by Indigenous children with reduced NPC.
Reduced positive fusional vergence

A higher percentage of Indigenous children met the CI criteria for reduced positive fusional vergence which is defined as failure of Sheard’s criterion (as applied to base out break point) and/or a positive fusional vergence break point of less than 15 prism dioptres. Factors that have been associated with positive fusional vergences include near phoria and near point of convergence; with reduced NPC and exophoria both being associated with a reduction in positive fusional vergence (Anderson et al., 2011). Ethnicity was not associated with positive fusional vergence in the latter study and there have been no other studies that have compared fusional vergence between ethnic groups. The current study showed that reduced NPC, exophoria at near and reduced positive fusional vergences were all more common in Indigenous children; furthermore, the current study is the first to report fusional vergence ranges in Australian Indigenous children.

In summary, a higher percentage of Indigenous children have reduced NPC and reduced positive fusional reserves, resulting in a higher prevalence of CI, compared with non-Indigenous children. Potential differences in intercanthal distance between the two groups may partially explain differences in near point of convergence, nevertheless, failing Sheard’s criterion (which was one of the parameters required for the classification of CI) is unrelated to intercanthal distance; therefore, CI in this study cannot be fully explained by a larger intercanthal distance. Identifying an association between CI and reduced reading ability (which is investigated in Chapter 5), as well as determining the impact severity of any related symptoms (using a standardised symptom survey), will help to establish the importance of the early detection of CI and management.

4.4.5 VISUAL INFORMATION PROCESSING SKILLS

Visual motor integration (VMI) and rapid automatised naming (RAN) skills have not been investigated previously in Australian Indigenous children. This is an important gap in the literature given the association that both skills have with reading ability (Kulp, 1999; Wolf & Bowers, 1999). VMI scores were significantly lower in Indigenous children; and although there was no difference in the group average RAN score between groups, more Indigenous children had a reduced RAN score (lower than one standard deviation below mean).
The overall mean VMI standard scores (Indigenous: 92.7 and non-Indigenous: 98.3) were lower than the expected standard score of 100. A lower performance may be due to the fact that all children in the current study attended schools located in areas of low socioeconomic status; and socioeconomic background has been associated with VMI. Children from higher socioeconomic backgrounds have been shown to score better than children from middle and low socioeconomic backgrounds (measured with the Beery test of VMI), (Bowman & Wallace, 1990; Dunn, Loxton, & Naidoo, 2006; Frey & Pinelli Jr, 1991). Low socioeconomic status is also a risk factor for motor, cognitive and social developmental delays (Golos, et al., 2011). Other tests of VMI (Developmental Test of Visual Motor Integration and Perception) have also shown to be affected by ethnic backgrounds as well as different language backgrounds (Dunn et al., 2006; Lai & Leung, 2012). Further investigations would be useful to determine whether the design of these tests is appropriate for detecting differences in VMI between ethnic groups.

Reduced RAN skills have been associated with language difficulties in children who experience language difficulties (Hatch, Pattison, & Richman, 1994). A language background other than English may also be associated with poorer RAN scores, as the child’s ability to perform the vertical subtests of the DEM may be affected. Many of the children in the current study had a language background other than English. This may have been because the schools were in low socioeconomic areas and tended to include high migrant populations. Furthermore, many Indigenous children speak another language at home (Department of Education and Training, 2011). These language-related factors may explain the high proportion of children who scored greater than one standard deviation above the expected mean, however, information regarding language background was not obtained in the current study.

The current study is the first to measure VMI and RAN skills in Indigenous children and showed that reduced VMI skills and/or RAN skills were more common in this group. Understanding the prevalence of reduced VMI and RAN in Indigenous children is beneficial given the functional implications of delayed visual information processing skills, particularly in terms of their association with reading disability. This association for the current cohort is explored in detail in Chapter 5.
4.4.6 COLOUR VISION

The prevalence of red-green colour vision deficiency (CVD) did not differ by Indigenous status for boys or girls in the current study. An unexpected finding was the difference in CVD between Indigenous boys living in metropolitan and rural areas (metropolitan: 16.7% and rural: 1.4%). This metropolitan-rural difference was only evident in this group, and not for Indigenous girls or non-Indigenous girls and boys.

Only one study has previously reported on the prevalence of CVD in Indigenous Australians living in rural communities in South Australia, showing there was significantly less CVD in that group compared with their non-Indigenous counterparts. The prevalence of CVD was 1.9% in Indigenous males and 0.03% in Indigenous females compared with 7.3% in white Australian males and 0.61% in white Australian females (Mann & Turner, 1956). The Ishihara colour vision test was used to classify CVD, however, the minimum number of errors required to diagnose a CVD in Mann and Turner’s study was not reported, which limits the ability to directly compare the prevalence data between studies, given that the specificity of the Ishihara test changes depending on the number of errors selected to classify a CVD (Dain, 2004). Other studies have also reported a low prevalence of CVD amongst Indigenous populations. Indigenous populations in Australia, Brazil, Fiji and North American have been shown to have the lowest rates of CVD, while some European populations have the highest rates of CVD (Post, 1982).

In Junghans et al.’s (2002) study, the prevalence of CVD was 7.68% in Australian children. In their study, two or more errors on the Ishihara colour test was used to classify CVD which may account for the higher prevalence of CVD in this study, compared with the current study. In addition, males and females were grouped together in their analysis, which is not commonly done in CVD prevalence studies given the genetically driven differences between males and females; Indigenous children were also not identified in Junghans et al.’s (2002) study.

4.5 CONCLUSION

The visual profile of Queensland Indigenous primary school children developed by the current study identified Indigenous children as having less visual impairment (based on reduced visual acuity), less clinically significant refractive
error and less strabismus than their non-Indigenous peers. However, CI appeared more prevalent in Indigenous children. Understanding the effect of CI in terms of its functional impact on educational outcomes, as well as the level of asthenopia caused, is critical given it is almost twice as common in this group. Reduced VMI and RAN skills were also more common in Indigenous children. This is important given the known association between visual information processing skills and reading outcomes, and will be explored in the next chapter.
Chapter 5: Vision conditions and their association with reading

5.1 BACKGROUND

The gap in educational outcomes between Australian Indigenous and non-Indigenous children has been well documented over the past decade following the State and Territory governments’ introduction of standardised national testing of literacy and numeracy. Indigenous children score lower in reading and numeracy skills than their non-Indigenous peers from a young age, and this gap widens as the child progresses through primary school (Australian Curriculum Assessment and Reporting Authority, 2011). Vision conditions are one of many factors that may potentially contribute to the reduced educational ability of a child, and therefore should be considered in underachieving children.

The impact that vision conditions may have on a child’s reading ability in the general population has been investigated and frequently debated amongst eye health professionals as well as educators. However, there has been no research that has investigated the effect that vision conditions have on the educational performance of Australian Indigenous children. This is clearly of relevance in light of the poor educational achievements of Indigenous children that have been reported.

A number of studies have shown an association between a range of eye conditions and reduced academic ability in children in the wider population; these conditions include uncorrected hyperopia, binocular vision dysfunction and poorly developed visual information processing skills (Chen et al., 2011; Garber, 1981; Godts et al., 1999; Goldstand et al., 2005; Kattouf & Steele, 2000; Krumholtz, 2000; Kulp & Schmidt, 1996; O'Grady, 1984; Palomo-Alvarez & Puell, 2008, 2009; Rosner & Rosner, 1997; Shankar et al., 2007; Shin et al., 2009; Williams et al., 2005; Woodrome & Johnson, 2009). Conversely, a number of other studies have failed to find any association between these vision conditions and academic ability (Dirani, Zhang, et al., 2010; Grisham et al., 2007; Helveston et al., 1985; Kedzia et al., 1999; Letourneau et al., 1979). Differences in study designs such as sample characteristics
and methodology, and inconsistent definitions of key terms are most likely to account for the discrepancy in the findings amongst previous studies.

It has also been proposed that certain vision conditions affect children in the earlier years of primary school while other conditions affect children in the later years of school. The ‘learning to read’ stage covers a younger age group of children (up to Year 3) than the ‘reading to learn’ stage and the tasks required in each stage impose different visual demands on the child (Chall & Jacobs, 1983). In the ‘learning to read’ stage, the print is large, more widely spaced and includes shorter words; reading is slow and the amount of information requiring processing is less (Borsting & Rouse, 1994; Dearborn, 1945; Pierce, 1977). In the ‘reading to learn’ stage, children are required to sustain higher levels of attention for longer periods of time and learning tasks may involve rapid and repeated changes in accommodation (Kulp & Schmidt, 1996). Adequate visual information processing skills are therefore more critical in children who are learning to read (younger age group) where visual analysis skills are required to differentiate between letters within words while efficient binocular vision and eye movement control may be more relevant to children reading to learn (older age group), (Kulp, 1999).

It is therefore surprising given this link between vision and academic outcomes in the wider population and the recent emphasis on Indigenous children’s reading skills, that the prevalence of hyperopia, binocular vision anomalies (such as accommodation and/or vergence disorders) and visual information processing conditions in Australian Indigenous children is not known, nor is the association between these conditions and reading ability in this group. This chapter describes the investigation of the impact of uncorrected hyperopia, convergence insufficiency (CI), reduced rapid automatised naming (RAN) and delayed visual motor integration (VMI) skills on reading outcomes in Indigenous and non-Indigenous children.

5.2 RESEARCH DESIGN

5.2.1 METHODOLOGY AND RESEARCH DESIGN

A cross-sectional correlational design was used to address the research question. In addition to the measures of vision described in Chapter 4, reading ability was assessed using the Neale Analysis of Reading Ability test.
The outcome variables included reading comprehension and reading accuracy, while the explanatory variables included uncorrected hyperopia, CI, reduced rapid automated naming (RAN) and reduced visual motor integration (VMI) skills. These vision conditions were selected as the explanatory variables because of their association with reduced reading ability as documented in existing literature (Krumholtz, 2000; Kulp, 1999; Rosner & Rosner, 1997; Shin et al., 2009; Wolf et al., 2000) and also their higher prevalence in Indigenous children (CI, reduced RAN and reduced VMI skills) found in the current study.

The following hypotheses were tested:

- Uncorrected hyperopia is associated with reduced reading ability in children;
- CI is associated with reduced reading ability and this is more evident in children in the later primary school years;
- Impaired visual information processing skills (VMI and RAN) are associated with reading ability and this is more evident in children in the younger year levels of primary school.

**Analytical approach**

Mean reading comprehension and reading accuracy scores for Indigenous and non-Indigenous children were reported by age group (Table 5.3-1). These were also reported for children with and without uncorrected hyperopia (Table 5.3-3), with and without CI (Table 5.3-6), with and without reduced RAN (Table 5.3-9) and with and without reduced VMI scores (Table 5.3-11). Full-factorial ANOVAs were performed for Indigenous and non-Indigenous children separately for each reading outcome and for each vision condition (considered as categorical variables) to assess whether the individual measures of vision and/or age group explained any variation in reading outcomes.

Step-wise mixed regressions were performed to determine the relationship between the various vision conditions (with the same data now considered as continuous variables) and reading ability. Different regression models were run for Indigenous and non-Indigenous children, as well as for the two different age groups for each of the reading outcomes. Different regression models were required for Indigenous and non-Indigenous children because Indigenous status was so strongly
associated with reading ability that the effect of the remaining variables could not be readily determined.

5.2.2 PARTICIPANTS

The same participant group described in Chapter 4 was included in this component of the research project. However, not all of the children performed or were able to complete the reading test for various reasons and were subsequently not included in this component of the research. The visual characteristics of the children who did not perform or complete the reading task were compared to the group that did complete the reading test.

5.2.3 INSTRUMENTS

Cycloplegic retinoscopy was used to measure and classify refractive error status including hyperopia. CI was classified based on subjective heterophoria, near point of convergence and fusional vergence results according to the CITT criteria (CITT Study Group, 2008). One language-related aspect of visual information processing was assessed using RAN, quantified using vertical subtests A and B of the Developmental Eye Movement Test. VMI was also measured using Beery’s test of Visual Motor Integration. A more detailed description of the instruments and procedure used to measure uncorrected hyperopia, CI, RAN and VMI is in Chapter 4. The Neale test of reading ability was also administered and is described below.

NEALE Analysis of Reading Ability (NEALE test)

The Neale test was first published in 1958, and is one of the most widely used reading ability tests in the United Kingdom, Australia and New Zealand (McKay, 1996). The Neale test was re-standardised for Australian school children and the revised edition was published in 1988.

The Neale test requires children to read aloud stories of increasing difficulty. At the end of each story comprehension questions are asked. The examiner counts any reading errors, and grades the comprehension questions. The time taken to complete each story is also recorded, and a reading rate score is determined. The total number of reading errors made provides a reading accuracy score, and the number of questions correctly answered provides a comprehension score (Spooner, Baddeley, & Gathercole, 2004). The Neale test was administered according to the instruction manual (Neale, 2008). The outcomes of accuracy and comprehension
were analysed in this study. This is because to read effectively, both of these skills are considered to be important. Children need to be able to decode print as well as understand its meaning (Nation & Snowling, 1997). Other studies using the Neale test, have also only used these two Neale outcomes to identify children with particular profiles across reading accuracy and reading comprehension (Nation & Snowling, 1997; Spooner et al., 2004). Raw scores were converted to percentile scores and adjusted for age - using “years of schooling” conversion tables provided in the Neale manual.

5.2.4 PROCEDURE AND TIMELINE

The procedure and timeline for this stage of the study was the same as that outlined in Chapter 4.

5.2.5 ETHICAL CLEARANCE

The ethical clearance detailed in Chapter 4 also covered this component of the research program.

5.3 RESULTS

Mean reading comprehension and reading accuracy results (as percentiles) for Indigenous and non-Indigenous children are presented in Table 5.3-1. The percentage distributions for both reading outcomes for each age group are presented in Figure 5.3-1 and Figure 5.3-2. The results demonstrate a gap in reading accuracy and reading comprehension between Indigenous and non-Indigenous children, with Indigenous children scoring significantly lower for both reading outcomes across both age groups. The mean reading comprehension and reading accuracy percentile scores for both Indigenous and non-Indigenous children were lower than the 50th percentile.
Table 5.3-1

Mean (± standard deviation) reading comprehension and reading accuracy percentile scores for Indigenous and non-Indigenous children by age group (significant differences are highlighted in bold text); for both outcomes, higher values represent better performance.

<table>
<thead>
<tr>
<th>Age group</th>
<th>Indigenous</th>
<th>Non-Indigenous</th>
<th>t-value, p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reading accuracy</td>
<td>Years 1 and 2</td>
<td>29.47 ± 28.25</td>
<td>40.05 ± 32.18</td>
</tr>
<tr>
<td></td>
<td>Years 6 and 7</td>
<td>32.62 ± 26.91</td>
<td>42.05 ± 31.03</td>
</tr>
<tr>
<td>Reading comprehension</td>
<td>Years 1 and 2</td>
<td>21.38 ± 26.32</td>
<td>37.25 ± 31.31</td>
</tr>
<tr>
<td></td>
<td>Years 6 and 7</td>
<td>23.27 ± 19.77</td>
<td>27.17 ± 24.81</td>
</tr>
</tbody>
</table>
Figure 5.3-1. Distribution of reading accuracy percentile scores by Indigenous status. Top figure - Years 1 and 2 children; bottom figure - Years 6 and 7 children
Figure 5.3-2. Distribution of reading comprehension percentile scores by Indigenous status.

Top figure - Years 1 and 2 children; bottom figure - Years 6 and 7 children
The visual profile of children who did not perform or complete the reading test is presented in Error! Not a valid bookmark self-reference. There were no significant differences in the prevalence of uncorrected hyperopia, reduced RAN and reduced VMI skills between those children who completed the reading task and those that did not. Interestingly, CI was significantly less prevalent in children who did not complete the reading test.

Table 5.3-2

<table>
<thead>
<tr>
<th></th>
<th>Did not complete reading test</th>
<th>Completed reading test</th>
<th>Chi-squared, p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uncorrected hyperopia</td>
<td>23.42%</td>
<td>23.97%</td>
<td>$\chi^2 (1, n = 549) = 0.02, p = 0.90$</td>
</tr>
<tr>
<td>Convergence insufficiency</td>
<td>1.94%</td>
<td>7.87%</td>
<td>$\chi^2 (1, n = 484) = 4.62, p = 0.03.$</td>
</tr>
<tr>
<td>Reduced RAN</td>
<td>43.09%</td>
<td>35.16%</td>
<td>$\chi^2 (1, n = 578) = 3.11, p = 0.08.$</td>
</tr>
<tr>
<td>Reduced VMI</td>
<td>50.39%</td>
<td>46.20%</td>
<td>$\chi^2 (1, n = 588) = 0.70, p = 0.40.$</td>
</tr>
</tbody>
</table>

*The different visual parameters (uncorrected hyperopia, CI, RAN and VMI) were not measured on all children; this resulted in different participant numbers for each visual parameter.

5.3.1 UNCORRECTED HYPEROPIA

Hyperopia was defined as a hyperopic refractive error of 1.50 dioptres or more in at least one eye. This definition allowed the findings to be compared directly with previous literature given that this criterion has been most commonly applied in studies that have assessed the relationship between hyperopia and reading ability (Krumholtz, 2000; Rosner & Rosner, 1997; Williams et al., 2005). This definition however is different to that used in Chapter 4 of this thesis. In Chapter 4, the definition of 2.00 dioptres or more in at least one eye was used as this could be compared to many other prevalence studies. Hyperopia was classified as uncorrected
when the child did not have spectacles. Using this definition, 19.21% of Indigenous and 26.08% of non-Indigenous children had uncorrected hyperopia, $\chi^2 (1, n = 549) = 3.11, p = 0.08$. Mean reading comprehension and reading accuracy percentile scores for Indigenous and non-Indigenous children with and without uncorrected hyperopia are presented in Table 5.3-3.

Table 5.3-3
Mean ± standard deviation reading comprehension and reading accuracy percentile scores for Indigenous and non-Indigenous children with and without uncorrected hyperopia, by age group

<table>
<thead>
<tr>
<th></th>
<th>Age group</th>
<th>Indigenous</th>
<th>Non-Indigenous</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>With uncorrected hyperopia</td>
<td>Without uncorrected hyperopia</td>
</tr>
<tr>
<td>Reading comprehension</td>
<td>Years 1 and 2</td>
<td>27.47 ± 27.26</td>
<td>19.50 ± 25.87</td>
</tr>
<tr>
<td></td>
<td>(n = 19)</td>
<td>(n = 70)</td>
<td>(n = 40)</td>
</tr>
<tr>
<td></td>
<td>Years 6 and 7</td>
<td>32.36 ± 23.28</td>
<td>21.22 ± 18.56</td>
</tr>
<tr>
<td></td>
<td>(n = 11)</td>
<td>(n = 49)</td>
<td>(n = 35)</td>
</tr>
<tr>
<td>Reading accuracy</td>
<td>Years 1 and 2</td>
<td>33.16 ± 28.95</td>
<td>28.83 ± 28.06</td>
</tr>
<tr>
<td></td>
<td>(n = 19)</td>
<td>(n = 71)</td>
<td>(n = 47)</td>
</tr>
<tr>
<td></td>
<td>Years 6 and 7</td>
<td>43.55 ± 23.55</td>
<td>30.16 ± 27.22</td>
</tr>
<tr>
<td></td>
<td>(n = 11)</td>
<td>(n = 49)</td>
<td>(n = 35)</td>
</tr>
</tbody>
</table>

*Fewer children completed the reading comprehension component of the Neale test; this resulted in fewer participants in this analysis with reading comprehension as the outcome measure.*
Full factorial ANOVAS which included Indigenous status, age group and uncorrected hyperopia as explanatory variables showed Indigenous status as the only factor that was associated with reading comprehension and reading accuracy age-adjusted percentile scores. Subsequently, full factorial ANOVAs were performed separately for Indigenous and non-Indigenous children to determine whether age group and/or uncorrected hyperopia were associated with reading comprehension and reading accuracy. The results of these ANOVAs are presented in Table 5.3-4 and Table 5.3-5.

Table 5.3-4

*Full-factorial ANOVA for reading accuracy; uncorrected hyperopia and year level are explanatory variables (significant findings are highlighted in bold text)*

<table>
<thead>
<tr>
<th>Reading accuracy</th>
<th>Indigenous</th>
<th></th>
<th>Non-Indigenous</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean ± sd</td>
<td>F-value</td>
<td>p-value</td>
<td>Mean ± sd</td>
<td>F-value</td>
<td>p-value</td>
</tr>
<tr>
<td><strong>Uncorrected hyperopia</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>With 36.97 ± 27.15</td>
<td>2.31</td>
<td>0.13</td>
<td>40.57 ± 29.73</td>
<td>0.27</td>
<td>0.60</td>
</tr>
<tr>
<td>Without 29.37 ± 27.59</td>
<td>43.01 ± 32.55</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Age group</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Years 1 and 2 29.73 ± 28.11</td>
<td>1.01</td>
<td>0.32</td>
<td>43.00 ± 32.14</td>
<td>0.02</td>
<td>0.90</td>
</tr>
<tr>
<td>Years 6 and 7 32.62 ± 26.91</td>
<td>41.73 ± 31.57</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Interaction (Uncorrected hyperopia*age group)</strong></td>
<td>0.60</td>
<td>0.44</td>
<td>0.93</td>
<td>0.34</td>
<td></td>
</tr>
</tbody>
</table>
Table 5.3-5  
Full-factorial ANOVA for reading comprehension; uncorrected hyperopia and year level are explanatory variables (significant findings are highlighted in bold text)

<table>
<thead>
<tr>
<th>Reading comprehension</th>
<th>Indigenous</th>
<th>Non-Indigenous</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± sd</td>
<td>F-value</td>
</tr>
<tr>
<td>Uncorrected hyperopia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>With</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29.27 ± 25.57</td>
<td></td>
<td>3.65</td>
</tr>
<tr>
<td>Without</td>
<td>20.20 ± 23.03</td>
<td>33.76 ± 29.73</td>
</tr>
<tr>
<td>0.10</td>
<td>0.75</td>
<td>0.13</td>
</tr>
</tbody>
</table>

Uncorrected hyperopia was not associated with reading accuracy or reading comprehension for either Indigenous or non-Indigenous children. Age group was associated with reading comprehension in non-Indigenous children; with children in the younger age group scoring higher in comparison with standardised scores in reading comprehension than older non-Indigenous children (see Table 5.3-5).

5.3.2 CONVERGENCE INSUFFICIENCY (CI)

Mean reading comprehension and reading accuracy percentile scores for Indigenous and non-Indigenous children with and without CI are presented in Table 5.3-6.
Table 5.3-6

Mean (± standard deviation) reading comprehension and reading accuracy percentile scores for Indigenous and non-Indigenous children with and without convergence insufficiency, by age group.

<table>
<thead>
<tr>
<th>Age group</th>
<th>Indigenous</th>
<th>Non-Indigenous</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>With CI</td>
<td>Without CI</td>
</tr>
<tr>
<td><strong>Reading</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>comprehension</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Years 1 and 2</td>
<td>23.67 ± 21.89</td>
<td>28.89 ± 28.77</td>
</tr>
<tr>
<td></td>
<td>(n = 6)</td>
<td>(n = 55)</td>
</tr>
<tr>
<td>Years 6 and 7</td>
<td>24.50 ± 17.30</td>
<td>23.94 ± 20.76</td>
</tr>
<tr>
<td></td>
<td>(n = 8)</td>
<td>(n = 48)</td>
</tr>
<tr>
<td><strong>Reading</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>accuracy</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Years 1 and 2</td>
<td>28.50 ± 34.80</td>
<td>36.48 ± 28.58</td>
</tr>
<tr>
<td></td>
<td>(n = 6)</td>
<td>(n = 56)</td>
</tr>
<tr>
<td>Years 6 and 7</td>
<td>31.75 ± 26.43</td>
<td>33.38 ± 26.63</td>
</tr>
<tr>
<td></td>
<td>(n = 8)</td>
<td>(n = 48)</td>
</tr>
</tbody>
</table>

*Fewer children completed the reading comprehension component of the Neale test; this resulted in fewer participants in the analysis with reading comprehension as the outcome measure.

Full-factorial ANOVAs were run for Indigenous and non-Indigenous children to determine whether the factors of age group and/or CI were associated with reading comprehension and reading accuracy. The results of these ANOVAs are presented in Table 5.3-7 and Table 5.3-8.
Table 5.3-7
Full-factorial ANOVAs for reading accuracy; convergence insufficiency and year level are explanatory variables

| Reading accuracy | Indigenous | | | Non-Indigenous | | |
|------------------|------------|-----------------|-----------------|-----------------|-----------------|
|                  | Mean ± sd  | F-value | p-value | Mean ± sd  | F-value | p-value |
| CI               |            |         |        |            |         |        |
| With             | 30.36 ±    | 0.36    | 0.55   | 42.39 ±    | 1.51    | 0.22    |
|                  | 29.06      |         |        | 31.12      |         |        |
| Without          | 35.04 ±    |         |        | 42.01 ±    |         |        |
|                  | 27.58      |         |        | 31.51      |         |        |
| Age group        |            |         |        |            |         |        |
| Years 1 and 2    | 35.69 ±    | 0.00    | 0.99   | 41.99 ±    | 2.50    | 0.16    |
|                  | 28.97      |         |        | 32.53      |         |        |
| Years 6 and 7    | 33.14 ±    |         |        | 42.08 ±    |         |        |
|                  | 26.36      |         |        | 30.53      |         |        |
| Interaction (CI*age group) | 0.16 | 0.69 | 2.75 | 0.10 |
Table 5.3-8
Full-factorial ANOVAs for reading comprehension; convergence insufficiency and year level are explanatory variables

<table>
<thead>
<tr>
<th></th>
<th>Indigenous</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Non-Indigenous</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± sd</td>
<td>F-value</td>
<td>p-value</td>
<td>Mean ± sd</td>
<td>F-value</td>
<td>p-value</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reading comprehension</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>With</td>
<td>24.14 ± 18.59</td>
<td>0.11</td>
<td>0.74</td>
<td>22.75 ± 23.03</td>
<td>1.82</td>
<td>0.18</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Without</td>
<td>26.57 ± 25.33</td>
<td></td>
<td></td>
<td>32.87 ± 28.62</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age group</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Years 1 and 2</td>
<td>28.36 ± 28.02</td>
<td>0.08</td>
<td>0.77</td>
<td>39.76 ± 31.44</td>
<td>0.05</td>
<td>0.82</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Years 6 and 7</td>
<td>24.02 ± 20.16</td>
<td></td>
<td></td>
<td>26.47 ± 24.34</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interaction (CI*age group)</td>
<td></td>
<td>0.17</td>
<td>0.69</td>
<td>1.34</td>
<td>0.25</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CI status was not associated with reading accuracy or reading comprehension in either Indigenous or non-Indigenous children.

5.3.3 RAPID AUTOMATISED NAMING (RAN)

Mean reading comprehension and reading accuracy percentile scores for Indigenous and non-Indigenous children with and without reduced RAN scores (lower than one standard deviation below mean) measured with the Developmental Eye Movement test are presented in Table 5.3-9.
Table 5.3-9

Mean (± standard deviation) reading comprehension and reading accuracy percentile scores for Indigenous and non-Indigenous children with and without reduced RAN scores (lower than one standard deviation below mean), by age group

<table>
<thead>
<tr>
<th>Age group</th>
<th>Indigenous</th>
<th>Non-Indigenous</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Reduced RAN</td>
<td>Not reduced RAN</td>
</tr>
<tr>
<td>Reading comprehension</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Years 1 and 2</td>
<td>12.46 ± 19.14</td>
<td>48.23 ± 27.36</td>
</tr>
<tr>
<td>(n = 67)</td>
<td>(n = 22)</td>
<td>(n = 97)</td>
</tr>
<tr>
<td>Years 6 and 7</td>
<td>18.60 ± 20.24</td>
<td>29.07 ± 18.42</td>
</tr>
<tr>
<td>(n = 30)</td>
<td>(n = 28)</td>
<td>(n = 76)</td>
</tr>
<tr>
<td>Reading accuracy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Years 1 and 2</td>
<td>20.10 ± 21.29</td>
<td>60.00 ± 26.85</td>
</tr>
<tr>
<td>(n = 69)</td>
<td>(n = 22)</td>
<td>(n = 126)</td>
</tr>
<tr>
<td>Years 6 and 7</td>
<td>20.60 ± 24.19</td>
<td>43.68 ± 23.08</td>
</tr>
<tr>
<td>(n = 30)</td>
<td>(n = 28)</td>
<td>(n = 81)</td>
</tr>
</tbody>
</table>

Full-factorial ANOVAs were run for Indigenous and non-Indigenous children to determine whether the factors of age group, hearing impairment and/or RAN were associated with reading comprehension and reading accuracy. Hearing impairment was also included in this analysis to determine whether there was an association between reading outcomes and hearing impairment overall, as well as to ascertain whether an interaction existed between RAN and hearing impairment in terms of reading outcomes. The results of these ANOVAs are presented in Table 5.3-10. RAN was used as a continuous variable for the ANOVA analysis.
Table 5.3-10

*Full-factorial ANOVAs for reading comprehension and reading accuracy; RAN and year level are explanatory variables (significant findings are highlighted in bold text)*

<table>
<thead>
<tr>
<th></th>
<th>Indigenous</th>
<th></th>
<th>Non-Indigenous</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F-value</td>
<td>p-value</td>
<td>F-value</td>
<td>p-value</td>
</tr>
<tr>
<td>Reading accuracy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RAN</td>
<td>14.26</td>
<td>&lt;0.01</td>
<td>75.76</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Age group</td>
<td>2.11</td>
<td>0.15</td>
<td>0.08</td>
<td>0.78</td>
</tr>
<tr>
<td>Hearing impairment</td>
<td>0.02</td>
<td>0.88</td>
<td>0.19</td>
<td>0.66</td>
</tr>
<tr>
<td>Interaction (RAN*age group)</td>
<td>0.13</td>
<td>0.72</td>
<td>6.80</td>
<td>0.01</td>
</tr>
<tr>
<td>Interaction (RAN*hearing impairment)</td>
<td>0.89</td>
<td>0.35</td>
<td>0.11</td>
<td>0.74</td>
</tr>
<tr>
<td>Reading comprehension</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RAN</td>
<td>4.02</td>
<td>0.05</td>
<td>23.92</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Age group</td>
<td>4.25</td>
<td>0.04</td>
<td>8.64</td>
<td>0.01</td>
</tr>
<tr>
<td>Hearing impairment</td>
<td>&lt;0.01</td>
<td>0.99</td>
<td>1.56</td>
<td>0.21</td>
</tr>
<tr>
<td>Interaction (RAN*age group)</td>
<td>2.19</td>
<td>0.14</td>
<td>0.40</td>
<td>0.53</td>
</tr>
<tr>
<td>Interaction (RAN*hearing impairment)</td>
<td>0.88</td>
<td>0.35</td>
<td>1.00</td>
<td>0.32</td>
</tr>
</tbody>
</table>

RAN was significantly associated with reduced reading comprehension and reading accuracy scores in Indigenous children and with reading comprehension scores only in non-Indigenous children. Age group was also associated with reading
comprehension scores (age-adjusted percentile scores) in both groups (see Table 5.3-1). Hearing impairment was not associated with reading accuracy or reading comprehension outcomes; the interaction between RAN and hearing impairment was also not associated with either of the reading outcomes.

There was a significant interaction between age group and RAN in non-Indigenous children for the reading outcome, reading accuracy. Further analysis revealed that there was a greater decrease in reading accuracy scores with reduced RAN in the older non-Indigenous age group, compared with the younger age group (Years 1 and 2: $\beta_{[\text{RAN}]} = -0.51$; Years 6 and 7: $\beta_{[\text{RAN}]} = -0.94$).

5.3.4 VISUAL MOTOR INTEGRATION (VMI)

Mean reading comprehension and reading accuracy percentile scores for Indigenous and non-Indigenous children with and without reduced VMI scores (lower than one standard deviation below mean) are presented in Table 5.3-11.
Table 5.3-11

Mean (± standard deviation) reading comprehension and reading accuracy percentile scores for Indigenous and non-Indigenous children with and without reduced VMI scores (lower than one standard deviation below mean), by age group

<table>
<thead>
<tr>
<th>Age group</th>
<th>Indigenous</th>
<th>Non-Indigenous</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Reduced VMI</td>
<td>Not reduced VMI</td>
</tr>
<tr>
<td><strong>Years 1 and 2</strong></td>
<td>14.65 ± 24.30</td>
<td>23.56 ± 26.81</td>
</tr>
<tr>
<td>(n = 20)</td>
<td>(n = 70)</td>
<td>(n = 20)</td>
</tr>
<tr>
<td><strong>Years 6 and 7</strong></td>
<td>19.14 ± 18.85</td>
<td>25.49 ± 20.13</td>
</tr>
<tr>
<td>(n = 21)</td>
<td>(n = 39)</td>
<td>(n = 32)</td>
</tr>
<tr>
<td><strong>Years 1 and 2</strong></td>
<td>22.10 ± 31.10</td>
<td>31.83 ± 27.33</td>
</tr>
<tr>
<td>(n = 20)</td>
<td>(n = 72)</td>
<td>(n = 24)</td>
</tr>
<tr>
<td><strong>Years 6 and 7</strong></td>
<td>20.62 ± 20.63</td>
<td>39.08 ± 27.89</td>
</tr>
<tr>
<td>(n = 21)</td>
<td>(n = 39)</td>
<td>(n = 33)</td>
</tr>
</tbody>
</table>

Full-factorial ANOVAs were run for Indigenous and non-Indigenous children to determine whether the factors of age group and/or VMI were associated with reading comprehension and reading accuracy. The results of these ANOVAs are presented in Table 5.3-12. VMI was used as a continuous variable for the ANOVA analysis.
Table 5.3-12
Full-factorial ANOVAs for reading comprehension and reading accuracy; VMI and year level are explanatory variables (significant findings are highlighted in bold text)

<table>
<thead>
<tr>
<th></th>
<th>Indigenous</th>
<th></th>
<th></th>
<th>Non-Indigenous</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F-value</td>
<td>p-value</td>
<td>F-value</td>
<td>p-value</td>
<td></td>
</tr>
<tr>
<td>Reading accuracy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VMI</td>
<td>20.94</td>
<td>&lt;0.01</td>
<td>29.62</td>
<td>&lt;0.01</td>
<td></td>
</tr>
<tr>
<td>Age group</td>
<td>0.49</td>
<td>0.49</td>
<td>0.02</td>
<td>0.90</td>
<td></td>
</tr>
<tr>
<td>Interaction (VMI*age group)</td>
<td>0.24</td>
<td>0.62</td>
<td>0.00</td>
<td>0.96</td>
<td></td>
</tr>
<tr>
<td>Reading comprehension</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VMI</td>
<td>15.51</td>
<td>&lt;0.01</td>
<td>31.98</td>
<td>&lt;0.01</td>
<td></td>
</tr>
<tr>
<td>Age group</td>
<td>5.36</td>
<td>0.02</td>
<td>2.72</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td>Interaction (VMI*age group)</td>
<td>4.78</td>
<td>0.03</td>
<td>4.46</td>
<td>0.04</td>
<td></td>
</tr>
</tbody>
</table>

VMI scores were significantly associated with reduced reading accuracy scores for Indigenous and non-Indigenous children. Significant interactions existed between VMI and age group for Indigenous children when reading comprehension was the response variable; there was a greater increase in reading comprehension scores with better VMI scores in the younger age groups, see Table 5.3-13.

Table 5.3-13
β values for linear regression with reading comprehension as response variable, VMI as explanatory variable

<table>
<thead>
<tr>
<th></th>
<th>Indigenous</th>
<th></th>
<th></th>
<th>Non-Indigenous</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F-value</td>
<td></td>
<td></td>
<td>F-value</td>
<td></td>
</tr>
<tr>
<td>Years 1 and 2</td>
<td>0.82</td>
<td></td>
<td></td>
<td>0.82</td>
<td></td>
</tr>
<tr>
<td>Years 6 and 7</td>
<td>0.23</td>
<td></td>
<td></td>
<td>0.37</td>
<td></td>
</tr>
</tbody>
</table>
5.3.5 ASSOCIATION BETWEEN DIFFERENT VISION MEASURES AND READING

Four step-wise mixed regressions were run for each response variable (reading comprehension and reading accuracy) using uncorrected hyperopia, CI, RAN and VMI as the explanatory variables. Regressions were performed separately for Indigenous and non-Indigenous children because when the regression was performed with all children included, Indigenous status was strongly associated with both reading outcomes. Regressions were run separately for each age group also because it has previously been shown that certain vision conditions have stronger associations with reading ability depending on the age group. Determining the amount of variation in reading comprehension and reading accuracy in these four groups (Years 1 and 2, Years 6 and 7, Indigenous and non-Indigenous) explained by these four vision measures (uncorrected hyperopia, CI, RAN and VMI) was the aim of this series of regressions. The most parsimonious model for each group for each reading variable is presented in Table 5.3-14 and Table 5.3-15.

Table 5.3-14
Results from the four step-wise mixed regressions for Indigenous and non-Indigenous children of two different age groups. Response variable = reading accuracy; explanatory variables = uncorrected hyperopia, convergence insufficiency, VMI and RAN

<table>
<thead>
<tr>
<th>Reading accuracy</th>
<th>Indigenous</th>
<th>Non-Indigenous</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Explanatory variables</td>
<td>β</td>
</tr>
<tr>
<td></td>
<td>RAN</td>
<td>-0.59</td>
</tr>
<tr>
<td>Years 1 and 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>VMI</td>
<td>0.55</td>
</tr>
<tr>
<td>Years 6 and 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 5.3-15
Results from the four step-wise mixed regressions for Indigenous and non-Indigenous children of two different age groups. Response variable = reading comprehension; explanatory variables = uncorrected hyperopia, convergence insufficiency, VMI and RAN

<table>
<thead>
<tr>
<th>Reading comprehension</th>
<th>Indigenous</th>
<th></th>
<th></th>
<th>Non-Indigenous</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Explanatory variables</td>
<td>β</td>
<td>F-value</td>
<td>p-value</td>
<td>Explanatory variables</td>
<td>β</td>
</tr>
<tr>
<td><strong>Years 1 and 2</strong></td>
<td>VMI</td>
<td>0.73</td>
<td>7.29</td>
<td><strong>0.01</strong></td>
<td>VMI</td>
<td>0.62</td>
</tr>
<tr>
<td></td>
<td>RAN</td>
<td>-0.32</td>
<td>5.89</td>
<td><strong>0.02</strong></td>
<td>RAN</td>
<td>-0.44</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Adjusted R-squared = 0.23</td>
<td></td>
</tr>
<tr>
<td></td>
<td>VMI</td>
<td>0.97</td>
<td>5.55</td>
<td><strong>0.02</strong></td>
<td>RAN</td>
<td>-0.45</td>
</tr>
<tr>
<td></td>
<td>RAN</td>
<td>1.25</td>
<td>3.50</td>
<td>0.07</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>VMI*RAN</td>
<td>-0.02</td>
<td>3.45</td>
<td>0.07</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Adjusted R-squared = 0.06</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Adjusted R-squared = 0.05</td>
<td></td>
</tr>
</tbody>
</table>

VMI and/or RAN were the two vision measures that explained the most variation in reading comprehension and reading accuracy. The amount of variation in these reading measures explained by each vision variable varied between Indigenous and non-Indigenous children, and children of different age groups.

VMI and RAN results explained a significant proportion of variance in reading comprehension scores in Years 1 and 2 Indigenous children. Twenty three percent (23%) of the variation in reading comprehension was explained by VMI and RAN and 28% of the variation in reading accuracy was explained by variations in RAN in this group.
5.4 DISCUSSION

The findings from this component of the study have shown that RAN and VMI dysfunction were strongly associated with reduced reading ability in Indigenous and non-Indigenous children. However, uncorrected hyperopia and CI were not associated with reduced reading ability.

5.4.1 UNCORRECTED HYPEROPIA AND READING ABILITY

The findings from the current study differ to those of many other studies. The majority of studies that have examined the relationship between hyperopia and academic ability have found positive associations (Bonilla-Warford, 2004; Borsting & Rouse, 1994; Christenson et al., 1990; Garzia & Nicholson, 1990; Grisham & Simons, 1986; Maples, 2003; Palomo-Alvarez & Puell, 2009; Rosner, 2004; Simons, 1993; Simons & Gassler, 1988; Spierer & Desatnik, 1998). What is unclear from these studies, however, is what level of hyperopia affects academic ability, as the definition used for hyperopia ranges from greater or equal to 0.25 dioptres and greater than three dioptres. Four separate studies have demonstrated that hyperopia of more than 1.50 dioptres was related to reduced academic performance (Godts et al., 1999; Krumholtz, 2000; Rosner & Rosner, 1997; Williams et al., 2005). Rosner and Rosner (1997) recommended that this level of hyperopia warranted correction in underachieving school children, independent of symptoms and visual acuity based on the results of their study (Rosner & Rosner, 1997). In a review article, Cotter concluded that despite an absence of randomised controlled clinical trials, many studies have shown that children with moderate hyperopia may be experiencing reading or academic problems. However, randomised controlled clinical trials are required in order to determine the level of hyperopia that should be corrected in children with reading or academic difficulties (Cotter, 2007).

There are many other risk factors that have been linked with reduced educational outcomes, including socio-economic status, ethnicity, educational background, low birth-weight, hearing impairments, decreased school attendance, low maternal education, male gender, less than two parents at home, and household cigarette exposure (Dirani, Zhang, et al., 2010; Kattouf & Steele, 2000; Ozmert et al., 2005). Almost one third of the children included in this study were Indigenous and all of the schools were located in areas of socio-economic disadvantage. Although data was not collected on all of the social factors listed above, decreased school
attendance is a well-known problem amongst Indigenous children (Collins, 1999), and many Indigenous children are affected by hearing impairment (Rothstein, Heazlewood, & Fraser, 2007). Australian Indigenous women are also more likely to deliver pre-term, or give birth to children of low birth weight at term (Roberts & Lancaster, 1999). However, this was not the case in the current study, where there was no difference in the prevalence of low birth weights between Indigenous and non-Indigenous children, although these data were obtained through self-report from the parents. Differences in methods for determining the prevalence of low birth weight between the current study and Roberts and Lancaster’s (1999) study may explain the contrasting findings. In the current study, low birth weight was parental-reported; whereas birth weight data was obtained from the Australian Institute of Health and Welfare National Perinatal Statistics Unit in Roberts and Lancaster’s (1999) study. It is plausible that in the sample of children included in this study, many factors associated with educational outcomes co-existed, thus the impact of hyperopia may have been masked by some of these additional factors. Furthermore, the number of children with high hyperopia was limited in this study; different results may have been obtained had a larger number of high hyperopes been included. Controlling for these factors (by measuring these variables using more appropriate methods than parental-reporting) in future studies may provide a more accurate representation of the effect of different vision variables on reading ability in this population; however, a much larger study than the current study would be required.

5.4.2 CONVERGENCE INSUFFICIENCY (CI) AND READING ABILITY

Convergence insufficiency (CI) was also not associated with reading ability in Indigenous children and non-Indigenous children. Findings from other studies that have investigated CI or other vergence dysfunctions and reading ability have reported mixed outcomes.

The effect of CI on academic behaviour was assessed by Rouse et al. (2009), finding that academic behaviour as reported by the child’s parents was significantly worse in children with CI compared with children with normal binocular vision. In Rouse et al.’s study, an academic behaviour survey (ABS) was completed by the child’s parents with questions covering whether their child had difficulty completing assignments and/or homework, appeared inattentive during near work, failed to show
attention to detail with their homework and whether the parent was worried about the child’s school performance; however the child’s actual reading ability was not recorded (Rouse et al., 2009). This is the only study identified that has used an ABS for comparing an accommodation and/or vergence disorder with academic behaviour. The significance of the positive association between CI and academic behaviour is limited however, due to the subjective nature of the ABS. It is possible that parents of children with a known eye condition, in this case CI, may report poorer academic behaviour in their child, if they feel the eye condition is affecting the child’s ability to learn. It has also been shown that some children with behavioural problems, such as Attention Deficit Disorder have difficulty with certain subjective optometric tests, such as near point of convergence (Evans, 2001), which may result in incorrect diagnosis of accommodation and/or vergence disorders.

Rouse et al.’s study also reported a significant difference in mean refractive error between the CI group and the normal binocular vision group, with the normal binocular vision group being more myopic. This difference in refractive error between the two groups may be a confounding factor, given that myopia has been associated with higher academic performance (Mutti et al., 2002).

Two individual measures of vergence function, near point of convergence and near horizontal fusional ranges, have been assessed in relation to academic ability in a range of studies (Evans, Drasdo, & Richards, 1994a; Evans et al., 1994b; Letourneau et al., 1979; Morad et al., 2002; Palomo-Alvarez & Puell, 2009; Shin et al., 2009). None of these studies found a significant association between vergence dysfunction and reduced academic ability; despite the fact that these studies targeted children in the ‘reading to learn stage’ (after Year 3), the stage in which binocular function is thought to be the most critical for reading ability (Borsting & Rouse, 1994; Chall & Jacobs, 1983). In these studies however, the use of a single measure to classify vergence dysfunction may not be an accurate representation of the true binocular status of a child, as compensatory mechanisms have not been considered. Multiple measures were used in the current study to classify CI to account for these compensatory mechanisms and categorise more accurately children with CI as well as other accommodation and/or vergence disorders.

Vergence dysfunction in association with accommodative dysfunction has been associated with reduced academic ability in Korean children (Shin et al., 2009). In
Shin et al.’s study, children aged between 9 and 13 years with combined accommodative and vergence dysfunction, such as accommodative insufficiency with CI and accommodative excess with CI as well as accommodative dysfunctions alone (accommodative insufficiency, accommodative infacility and accommodative excess) had mean academic scores significantly lower than a control group. Interestingly, children with a vergence dysfunction alone (i.e. no associated accommodative dysfunction), did not show any difference in their mean academic scores compared with those of the control group. The results of the current study support Shin et al.’s findings of a lack of an association between vergence dysfunction and reduced reading ability. A limitation of the current study, however, is the small number of children included that were classified with CI. Thirty two children with CI participated in the study, whereas the power analysis performed required 37 participants with CI. It is possible therefore that the effect of CI was marginally underestimated due to sampling issues.

Accommodative dysfunction was not assessed independently in the current study. This was due to the fact that the majority of accommodative measures are recorded subjectively. Given the age range of the children participating in this study, objective measures of binocular vision were primarily selected. Measurement of accommodative function (e.g. amplitude of accommodation) in Indigenous children in the later years of primary school, where subjective assessment is more appropriate, would be a useful area for future research as this has not been previously investigated. Objective assessment of accommodative function, such as MEM retinoscopy to measure accommodative lag, in Indigenous children would also be beneficial, in order to allow for the classification of accommodation disorders.

5.4.3 RAPID AUTOMATISED NAMING (RAN) AND READING ABILITY

In the current study, reduced Rapid Automatised Naming (RAN) ability, as assessed with the vertical subtests of the DEM, was strongly associated with reduced reading ability in Indigenous and non-Indigenous children. These findings are in general accord with other studies that have shown that RAN tasks are most strongly associated with reading ability in children (Koponen, Salmi, Eklund, & Aro, 2013; Norton & Wolf, 2012; Wolf et al., 2000). Due to the experimental design of this study, however, it is only possible to determine whether there are associations between variables rather than causality. This design does not allow determination of
whether reduced RAN causes reduced reading ability, whether reduced reading ability causes reduced RAN or whether the two variables are non-causal correlates.

RAN is the second deficit in the double deficit hypothesis; with the first being a deficit in phonological processing. Historically, it was believed that reading disability was due to a deficit in phonological processing skills, which affected word recognition skills, which in turn affected reading fluency (Wolf & Bowers, 1999). As a result, phonological processing has been the main area investigated in reading research (Wolf et al., 2002). However, certain areas of reading disability are not explained by phonological awareness; one example being the case of children with reading disability who were unable to improve following phonological-based interventions (Wolf & Bowers, 2000). Subsequently, the double-deficit hypothesis was proposed as an alternative conceptualisation of reading disability (Wolf & Bowers, 1999). This was due to the wide range of evidence showing that a deficit in RAN was associated with reduced reading ability. In the double-deficit hypothesis, phonological deficits and the processes underlying RAN deficits are two largely independent causes of reading dysfunction, although they can occur simultaneously. One proposed explanation for the association between RAN and reading ability is that RAN is an indication of the automaticity with which letter codes are accessed in memory, and the automatisation of this process is required in the reading process (Spring & Davis, 1988).

The findings from the current study agree with the studies listed above that show an association between reduced RAN skills and impaired reading ability, and importantly this study is the first to show that this is also the case for both Indigenous and non-Indigenous children.

5.4.4 VISUAL MOTOR INTEGRATION (VMI)

Delayed VMI (measured with Beery’s Developmental Test of Visual Motor Integration) was significantly associated with reduced reading ability in Indigenous and non-Indigenous children. This is in agreement with findings of numerous other authors who have shown that an association exists between impaired VMI and reduced reading outcomes (Geldof, van Wassenaer, de Kieviet, Kok, & Oosterlaan, 2012; Kavale, 1982; Kulp, 1999; Kulp & Sortor, 2003; Rosner & Rosner, 1987; Sortor & Kulp, 2003; Tekok-Kilic, Elmastas-Dikec, & Can, 2010). This may be because the activities of both reading and performing Beery’s test of VMI require
adequate visual analysis skills; that is, the ability to differentiate between letters, shapes and symbols is required by both tasks.

Two studies that used the same test of VMI as that used in the current study compared VMI scores with reading ability in Years 2 – 4 children (Sortor & Kulp, 2003) and Kindergarten – Year 3 children (Kulp, 1999). In the first study, a significant difference in VMI performance was found between children in the lower and upper quartiles of reading, with children in the upper reading quartile scoring higher (Sortor & Kulp, 2003); and in the second study, VMI skills were significantly correlated to reading, mathematics, writing and spelling ability (Kulp, 1999).

In contrast, a study performed on Year 7 children found no difference in VMI scores between proficient and non-proficient readers; reading ability was measured with the Altalef Reading Screening test (Goldstand et al., 2005). The authors proposed that one explanation for the lack of an association between reading and VMI was that the relationship between vision and reading changes with age, with the task of reading changing as the child progresses through school. This was also the case in the current study where a difference in reading comprehension between children with a VMI dysfunction and those with normal VMI was greatest in the younger age group. This theory is supported by other authors that have also indicated that the role of VMI is most important in the younger year levels (Borsting & Rouse, 1994; Kavale, 1982; Kulp, 1999).

5.5 CONCLUSION

Uncorrected hyperopia, CI, reduced RAN and VMI dysfunction were assessed in terms of their effect on reading ability in a cohort of Indigenous and non-Indigenous children. Both reduced RAN and reduced VMI were associated with poorer reading outcomes in Indigenous and non-Indigenous children. With recent emphasis being placed on Indigenous children’s reading skills, this is an important finding, especially given that reduced RAN and VMI skills were shown to be more common in Indigenous children (see Chapter 4).

The demonstrated association between RAN and VMI and reading ability has important implications in terms of future research. A logical next step would be to establish whether reduced RAN and VMI cause reduced reading outcomes, as well as to determine whether an intervention program designed specifically at improving
VMI and RAN skills in Indigenous children would have a positive effect on their reading outcomes. As a minimum, assessment of VMI and RAN skills should be considered in eye examinations (or vision screenings) in children who are underachieving academically.
Chapter 6: Vision screening services in Queensland

6.1 BACKGROUND

Vision screenings are an important method of identifying vision problems in children who otherwise may not present for eye examinations. The extent and nature of vision screening services that are provided to Australian children however is not well understood, with considerable inconsistency between states and territories regarding screening services and protocols. Whilst this thesis specifically aimed to characterise the visual profile of Indigenous Australian children, a lack of consistent and widespread vision screening affects both Indigenous and non-Indigenous children and is therefore important to consider. This chapter presents the results of a survey study that investigated the current provision of vision screening services to Queensland children.

6.2 AIM

This survey study aimed to identify the extent of geographical coverage of children’s vision screening services in one Australian state, (Queensland) as well as investigate which vision tests are included in screenings and the corresponding referral criteria that are adopted. The study considered whether existing vision screenings in general meet the needs of Indigenous children, based on the prevalence of paediatric vision conditions identified in Chapter 4 of this thesis and whether the vision screenings target those visual conditions that have been shown to be associated with reading ability (Chapter 5).

6.3 RESEARCH DESIGN

6.3.1 METHODOLOGY

Two cross-sectional surveys were used to evaluate the vision screening services available to Queensland children. One survey was distributed to Queensland Health nurses and the second to Queensland optometrists, given that both groups were assumed to be actively involved in children’s vision screenings.
The questions in the surveys were designed to address the following three research issues:

- What is the coverage of children’s vision screenings by Queensland Health nurses and Queensland optometrists?
- What tests are being included in the vision screenings?
- What is the referral criterion for each test outcome?

Surveys are commonly used in research as they are a convenient and inexpensive method compared with interviews (Kumar, 2011). Surveys can either be completed online or through the traditional approach of a paper version of the survey mailed to potential participants. There are a number of advantages of using an online approach. Distribution and completion of surveys via online methods (email and website completion) has been shown to result in higher completion rates (Kongsved, Basnov, Holm-Christensen, & Hjollund, 2007). A second benefit of online surveys is that the online design can compensate for human error, such as accidentally skipping questions or entering inconsistent answers by prompting a valid response. Online surveys are also less costly and more environmentally responsible than mailed surveys when using existing survey development websites (Leece et al., 2004). However, although the completion rate (of each individual survey) is higher with online surveys, the response rate is lower compared with mailed surveys (Augustsson Balter, Balter, Fondel, & Trolle Lagerros, 2005; Kongsved et al., 2007; Leece et al., 2004); potential respondents are less likely to respond to an online survey than a mailed survey.

Given the reported advantages of online surveys in terms of completion rates, as well as cost and convenience, an online survey was used for the optometrist cohort. This was because there were larger numbers of optometrists and the emphasis could be placed on survey completion rather than response rate. A smaller number of potential participants existed in the Queensland Health nurse cohort; in this case it was decided that a mailed survey would be the best survey method in order to maximise response rates.
6.3.2 PARTICIPANTS

Queensland Health nurses

There are 15 Queensland health service districts (HSDs), see Figure 6.3-1, in which there are 182 sites (hospitals or health centres). Fourteen of the 15 HSDs consented to participate in this study; accordingly, surveys were mailed to the 140 sites located within these 14 HSDs.

Figure 6.3-1. Queensland Health Service Districts (The State of Queensland (Queensland Health), 2012)

One nurse from each of the 140 sites was asked to complete the survey. The respondent to the survey was considered to be site specific, and a clinical, community, school-based or Royal Flying Doctor Service nurse completed the

Chapter 6: Vision screening services in Queensland
survey on behalf of the site. Two follow-up letters were sent (in addition to the initial contact) to those sites that had not returned a survey. Of the 140 sites that were sent surveys, 88 returned a completed survey, which represents a 63% response rate. This response is similar to the mean response rate of 61% for nurses to mailed surveys reported in other studies (Asch, Jedrzewski, & Christakis, 1997).

Optometrists

The survey was made available to Queensland-registered optometrists via the online SEE magazine, the monthly newsletter of the Optometrists Association Australia (OAA), Queensland and Northern Territory Division as well as via group email (from OAA, QLD and NT). Three follow-up contacts were made in addition to the initial contact, with very few additional responses being submitted after the third follow-up. These follow-ups were made via the monthly newsletter as well as via email. One hundred and fifty-nine of the 914 optometrists registered in Queensland responded to the online survey. This equates to a response rate of 17.4%, which falls within the expected response rate range of 7 – 44% for online surveys (Schonlau, Fricker, & Elliott, 2002).

6.3.3 INSTRUMENTS

The instruments used for data collection were a mailed paper survey for nurses and an online survey for optometrists (see Appendix K). The two surveys were different as the questions were tailored to the two different participant groups.

Both the mailed and online surveys were created after considering the sequence of questions to be asked (including the use and placement of filter questions), and question types (Oppenheim, 1992). Filter questions are designed to exclude respondents from answering a particular series of questions if the questions are irrelevant to the respondent. Filter questions were used in both the mailed and online survey to ensure respondents were only answering questions specific to their own situation.

Mixtures of open and closed questions were used in both surveys. In closed questions, respondents are offered a choice of alternative replies. This type of question requires little time to answer and is easy to analyse. Open questions do not offer a choice of responses and instead, the respondent records their own answer in full. This type of question is more time-consuming, however it allows for a wider
range of responses by providing the respondent freedom on how the question can be answered (Oppenheim, 1992).

The online survey for optometrists comprised 25 questions. The questions covered whether the optometrist had been involved in children’s vision screenings, the location of the screenings, age group assessed, tests performed and referral criteria. The survey also covered questions about children seen by the optometrist in their practice who were referred from a screening. Examples of some of the questions included in the optometrist survey include:

- In the last year, have you been involved in any vision screenings on primary school children outside of your practice?
- In what regions of Queensland have you participated in vision screenings?
- Which of the following tests are included in the vision screenings?
- In the last year, have you seen any primary school children who came to you because they had failed a vision screening?

The same HSDs (except for Children’s HSD) were used to determine the different regions in the optometrist survey and subsequent analysis. The Children’s HSD was not used as this is not a geographic region. The online survey was created with KeySurvey V7.4 (WorldAPP Key Survey [2011]. KeySurvey. Braintree, MA: WorldAPP). KeySurvey is a web-based survey creation and management system.

The mailed survey for nurses comprised 10 questions. Questions covered whether vision screenings were performed from that site, with specific questions relating to the location of the screenings, age group seen, tests included in the screenings and referral criteria. Examples of some of the questions included in the nurse survey were:

- Are vision screenings conducted on kindergarten – year 1 children (aged between four and seven years) in your region? (This can include vision screenings conducted in combination with other screenings, such as hearing);
- What tests are included in the vision screening? E.g. STYCAR visual acuity testing, cover test.
6.3.4 ETHICAL CLEARANCE

A low risk ethics application was submitted and approved by Queensland University of Technology Human Research Ethics Committee on November 30, 2010 to survey Queensland-registered optometrists on their involvement with children’s vision screenings. A second low risk application was submitted and approved by the Queensland Government Office of Health and Medical Research Human Research Ethics Committee on February 25, 2011 to survey Queensland Health nurses about their involvement with children’s vision screenings.

6.4 ANALYSIS

The results and discussion sections are presented concurrently in this chapter. Each section focuses on one of three research questions (see section 6.3.1) instead of discussing each survey question individually. The results have been presented in response frequency tables relating to each of the research questions.

6.4.1 COVERAGE OF CHILDREN’S VISION SCREENINGS

The number of nurses and optometrists that had been involved with at least one children’s vision screening in 2010/2011 is presented in Table 6.4-1. The number of nurses represents the number of Queensland Health sites involved. This is because only one nurse per Queensland Health site completed the survey, and responses were based on services provided by the site (not the individual nurse). Rural Queensland was classified as any Health Service District (HSD) that did not include Metro North, Metro South, Gold Coast or the Sunshine Coast.
Table 6.4-1
Number of nurses (sites) and optometrists who had participated in at least one vision screening in 2010/2011

<table>
<thead>
<tr>
<th></th>
<th>Nurses</th>
<th>Optometrists</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Queensland Health sites)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brisbane, Gold and Sunshine Coasts</td>
<td>3/7 (43%)</td>
<td>20/116 (17%)</td>
</tr>
<tr>
<td>Rural Queensland</td>
<td>45/81 (56%)</td>
<td>8/36 (22%)</td>
</tr>
<tr>
<td>Total</td>
<td>48/88 (55%)</td>
<td>28/152 (18%)</td>
</tr>
</tbody>
</table>

*Only 152/159 of the optometrists provided a response regarding whether or not they had participated in a vision screening in the past year.

The breakdown of responses for each HSD as well as the number of respondents who reported being involved in vision screenings is presented in Table 6.4-2. The total number of responses by optometrists for each region (n = 192) exceeds the number of optometrists who participated in the survey (n = 159) as a number of optometrists reported practicing across several regions.
Table 6.4-2
Number of responses by nurses and optometrists for each HSD, as well as the percentage involved in vision screenings. Bold responses indicate the HSDs where more than half of the respondents were involved in screenings

<table>
<thead>
<tr>
<th>HSD</th>
<th>Nurses (Queensland Health sites)</th>
<th>Optometrists</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of responses/number of sites</td>
<td>Involved in screening</td>
</tr>
<tr>
<td>Metro North</td>
<td>n/a*</td>
<td>n/a</td>
</tr>
<tr>
<td>Metro South</td>
<td>n/a*</td>
<td>n/a</td>
</tr>
<tr>
<td>Children’s</td>
<td>3/30 66%</td>
<td>n/a†</td>
</tr>
<tr>
<td>Gold Coast</td>
<td>n/a**</td>
<td>n/a</td>
</tr>
<tr>
<td>Sunshine Coast</td>
<td>4/4 25%</td>
<td>n/a</td>
</tr>
<tr>
<td>West Moreton - Darling Downs</td>
<td>15/17 66%</td>
<td>17</td>
</tr>
<tr>
<td>Wide Bay</td>
<td>10/11 33%</td>
<td>n/a‡</td>
</tr>
<tr>
<td>Central Queensland</td>
<td>5/6 60%</td>
<td>7</td>
</tr>
<tr>
<td>South West</td>
<td>8/11 13%</td>
<td>4</td>
</tr>
<tr>
<td>Central West</td>
<td>8/10 63%</td>
<td>2</td>
</tr>
<tr>
<td>Mackay</td>
<td>3/3 33%</td>
<td>6</td>
</tr>
<tr>
<td>Townsville</td>
<td>8/9 38%</td>
<td>6</td>
</tr>
<tr>
<td>North West</td>
<td>4/9 75%</td>
<td>2</td>
</tr>
<tr>
<td>Cairns and Hinterland</td>
<td>15/18 80%</td>
<td>8</td>
</tr>
<tr>
<td>Cape York</td>
<td>4/11 100%</td>
<td>1</td>
</tr>
<tr>
<td>Torres Strait – Northern Peninsula</td>
<td>1/1 0%</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>88/140 55%</td>
<td>192</td>
</tr>
</tbody>
</table>

*Metro North, Metro South and Children’s HSD responses for the nurses were combined as required by ethics approval

**Ethical approval was not granted to include nurses from the Gold Coast HSD in this research

†The Children’s HSD was not included as a region in the optometrist survey

‡Sunshine Coast and Wide Bay were grouped as one region in the optometrist survey (Wide Bay responses are included in Sunshine Coast’s figures)
Nurses

All HSDs except the Torres Strait – Northern Peninsula had sites involved in vision screenings. The HSDs of Cairns, Cape York and North West were well serviced, with at least three quarters of the sites reporting that they participate in vision screenings. Overall, over half of the Queensland Health sites that responded to the survey reported being involved with children’s vision screenings.

More responses were received from Queensland Health sites in rural Queensland (compared with the metropolitan and Sunshine Coast HSDs) with a response rate of 76% achieved in these regions. The findings relating to the provision of vision screenings by Queensland Health nurses to children living in rural Queensland are therefore a good representation of nurses’ involvement in general across these regions. Only seven responses of a possible 34 were returned from nurses from metropolitan HSDs and the Sunshine Coast (Gold Coast was not included in the study as ethical approval was not granted), equating to a low response rate which may not necessarily represent the involvement of these regions.

Optometrists

Greater numbers of optometrists from metropolitan, Sunshine and Gold Coast HSDs responded to the survey, compared with optometrists practising in rural Queensland. This is most likely due to the fact that a larger number of optometrists practise in these HSDs compared with rural Queensland. The number of optometrists currently practising in each HSD could not be measured given the nature of optometry work; that is, many optometrists travel to rural areas for locum work and also, optometrists may work in more than one region.

Approximately one fifth of optometrists from the metropolitan HSDs and Sunshine Coast reported being involved with vision screenings. Fewer optometrists were involved with vision screenings on the Gold Coast and in rural Queensland, with the exception of Cape York, Cairns and West Moreton-Darling Downs, see Table 6.4-2.

The location where vision screenings are performed is presented in Table 6.4-3. The most common location for children’s vision screenings is at local primary schools; and some sites provided screenings at multiple locations. Despite optometrists and nurses performing vision screenings at the same locations, neither
nurses nor optometrists reported liaising with each other with regards to these vision screenings.

Table 6.4-3

<table>
<thead>
<tr>
<th>Location</th>
<th>Nurses</th>
<th>Optometrists</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary School</td>
<td>36</td>
<td>27</td>
</tr>
<tr>
<td>Kindergarten</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Health Centre</td>
<td>24</td>
<td>0</td>
</tr>
<tr>
<td>Hospital</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Queensland Health guidelines for screening and surveillance in the early detection of childhood health conditions advise that all children be screened for reduced visual acuity and strabismus at age four to five years, as well as receive up to seven vision screenings between the ages of 0 – 3.5 years by the child health nurse (Morcos & Wright, 2009). These guidelines recommend more vision screenings be undertaken than was proposed by the Project Advisory Group (PAG) of the National Children’s Vision Screening Project (NCVSP). The PAG recommended vision assessment be performed at birth, at three to six months and at four years of age (year prior to school). The PAG’s recommendation was made, however, despite a lack of evidence found in the NCVSP’s literature review supporting vision screening of children aged three to six months. The PAG advocated that screening of this age group was important to ensure that any vision problems missed at the neonatal check could be detected. The PAG also recommended visual screening at age four years rather than from eighteen months of age, as recommended by the initial review, on the basis of the decreased ability of younger children to complete screening procedures effectively.

The Royal Australian and New Zealand College of Ophthalmology and the Orthoptists Association Australia also recommend that all children be screened by age five years (Morcos & Wright, 2009; Royal Australian and New Zealand College of Ophthalmology (RANZCO), 2006). Conversely, the Optometrists Association
Australia has no guidelines or position statement regarding the age at which children should undergo vision screening.

It is highly unlikely that all children aged four to five years are screened by nurses or optometrists in Queensland given the findings of the current study. Only 55% of Queensland Health sites who reportedly specialise in child health, community health and/or had a school screening service as outlined by Queensland Health on their website (Queensland Health, 2013) actually performed screenings, and even fewer optometrists were involved (18%). Overlap may exist between screenings provided by Queensland Health nurses and local optometrists, which would result in a lower overall coverage, given the duplication of service. This possible overlap could not be determined in the current study, but would be a useful question to address when mapping out service provision in the future.

A higher proportion of Queensland Health sites and/or optometrists need to be involved in vision screenings, particularly in rural Queensland (given the distances needed to travel between services), if Queensland Health’s guidelines are to be met. It would appear that an issue with service delivery exists given that neither Queensland Health nor RANZCO’s recommendations are currently being met.

The role of the general practitioner in children’s vision screenings was not considered by this study as it is believed to have minimal influence on screening numbers overall. The Healthy Kids Check (HKC) is a Federal Government sponsored health screening program administered within general medical practices and targets four year old children (Australian Government Department of Health and Ageing, 2012b). The HKC guidelines recommend referral to an optometrist in the event of concerns by the general practitioner or nurse who administers the screening (Australian Government Department of Health and Ageing, 2012a); however, the guidelines do not provide any criteria for what constitutes a ‘concern’. The NCVSP reported a low rate of uptake of the HKC and no data appears to be shared between or within jurisdictions. This means other providers of vision screening programs are not aware of which children have previously been screened as part of the HKC (Morcos & Wright, 2009), consistent with the low level of information sharing associated with vision screenings generally.

Outside Australia, Sweden’s screening program also recommends that children receive numerous vision screenings prior to school. This program recommends that
by the age of four, children should have received six vision screenings, followed by two additional screenings during primary school. This large number of vision screenings has meant that 99% of four year old Swedish children have participated in at least one vision screening. There has been a notable reduction in the prevalence of amblyopia in Sweden since the implementation of this screening program (0.2% in 1992 compared with 2.0% in 1970), (Hard, 2007; Kvarnstrom, Jakobson, & Lennerstrand, 2001). Further research would be beneficial in Australia to determine the proportion of children who have had at least one vision screening prior to school, and whether this figure is greater in those states that recommend a specific number of vision screenings before school age. It would also be valuable to determine whether states that recommend a greater number of screenings have a lower prevalence of treatable paediatric eye conditions such as amblyopia and uncorrected refractive error.

The current study has established that the coverage of children’s vision screening services across Queensland is inadequate in terms of meeting current service delivery recommendations. Some HSDs within Queensland such as Torres Strait and Northern Peninsula, Sunshine Coast, Gold Coast, Wide Bay, South West, Mackay and Townsville have a low provision of children’s vision screening services. Limited access to vision screening services for Queensland children is a concern, and is likely to result in important vision conditions not being detected and managed at an early age. The prognosis for a number of paediatric conditions, such as significant refractive error or strabismus, may be poorer if initial management is delayed. In addition, untreated eye conditions may have an impact on children’s educational outcomes (see Chapter 5); and in a small number of cases, the prognosis of rare paediatric eye conditions may be fatal. Identifying these pathological conditions in particular at the earliest possible stage is critical either via a routine eye examination or a vision screening.

6.4.2 VISION SCREENING TESTS

A list of the different tests included in children’s vision screenings by nurses and optometrists is presented in Table 6.4-4. The responses were from nurses and optometrists who had previously been involved with screenings and who had completed the question.
Table 6.4-4

Percentage of nurses and optometrists that performed specific vision tests in children’s vision screenings

<table>
<thead>
<tr>
<th>Test Type</th>
<th>Nurses (n = 45)</th>
<th>Optometrists (n = 27)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vision/refractive error</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual acuity</td>
<td>93%</td>
<td>100%</td>
</tr>
<tr>
<td>Hyperopia (plus lens test)</td>
<td>7%</td>
<td>19%</td>
</tr>
<tr>
<td>Refraction</td>
<td>0%</td>
<td>11%</td>
</tr>
<tr>
<td><strong>Binocular vision</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strabismus assessment (cover test/Hirschberg test)</td>
<td>78%</td>
<td>85%</td>
</tr>
<tr>
<td>Stereoacuity</td>
<td>7%</td>
<td>100%</td>
</tr>
<tr>
<td>Motility</td>
<td>4%</td>
<td>26%</td>
</tr>
<tr>
<td>Near point of convergence</td>
<td>2%</td>
<td>22%</td>
</tr>
<tr>
<td>Phoria measurement (test not specified)</td>
<td>0%</td>
<td>11%</td>
</tr>
<tr>
<td><strong>Colour vision</strong></td>
<td>11%</td>
<td>93%</td>
</tr>
<tr>
<td><strong>Ocular health</strong></td>
<td>0%</td>
<td>15%</td>
</tr>
<tr>
<td>Two responses included a description of tests used:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>i) ophthalmoscopy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ii) pupils/Burton lamp/MIO*</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hearing</td>
<td>96%</td>
<td>n/a</td>
</tr>
<tr>
<td>Height/weight</td>
<td>61%</td>
<td>n/a</td>
</tr>
</tbody>
</table>

*MIO = monocular indirect ophthalmoscope

In addition to the tests included in Table 6.4-4, one optometrist reported performing a visual information processing test as part of the screening, and one of the nurses used a computerised vision screener. Computerised screeners are software programs designed for non-ophthalmically trained health professionals to screen for
a number of vision conditions, such as binocular, accommodative, ocular motor
disorders, hyperopia and visual acuity (Gallaway & Mitchell, 2010). However,
further descriptions of the tests were not provided so are not included in the table.

Visual acuity testing in conjunction with the cover test was used as the
minimum testing battery by 75% of the nurses to screen vision. In comparison, 70%
of optometrists reported using a minimum of the following four tests in vision
screenings: visual acuity, cover test, stereoacuity and colour vision testing.

These findings suggest that in Queensland there is no uniform battery of tests
used in children’s vision screenings by nurses or optometrists. While the majority of
screenings measured visual acuity and screened for strabismus, the specific tests used
varied between respondents. A large number of optometrists also included colour
vision and stereoacuity tests as part of the screening. Additional tests of binocular
vision, visual information processing and/or ocular health were only performed by a
small number of nurses and optometrists.

Given these findings, it would appear that the tests included in vision
screenings are not addressing the most critical visual needs of children. Hyperopia is
the most common refractive error in Australian primary school children and has been
associated with reduced academic performance in the wider population (Ip, Robaei,
et al., 2008; Rosner & Rosner, 1997). Yet less than one third of optometrists and less
than one in ten nurses tested for low to moderate levels of hyperopia (hyperopia plus
lens test or a refraction) that may not be detected with a visual acuity test.

Accommodation and/or vergence disorders have also been linked with reduced
academic performance (Palomo-Alvarez & Puell, 2008) and are also common
paediatric eye conditions (Scheiman et al., 1996). Tests for detecting strabismus and
amblyopia were performed by many of the nurses and optometrists (visual acuity
testing and the cover test or Hirschberg test). Stereoacuity testing was also
performed by all of the surveyed optometrists. Tests for non-strabismic binocular
vision conditions (such as accommodation and/or vergence disorders), however,
were much less common, with only a small number of optometrists and nurses
performing extra tests. This is particularly relevant to Indigenous children who were
shown through the research involved in this thesis to have a higher prevalence of CI
(Chapter 4). One fifth of optometrists screened for a reduced near point of
convergence, fewer still measured phorias, and none measured fusional reserves or
any accommodative measures. Given the association between a number of non-strabismic binocular vision conditions and educational outcomes, and the prevalence of these conditions in school children, it is of concern that so few binocular vision tests are included in screenings. Early detection and management of these conditions may positively impact on the educational outcomes of some children and address symptoms of asthenopia and reduced concentration.

Ocular health assessments were also only performed by a small number of optometrists. The consequences of missing some paediatric eye conditions can be substantial. It is therefore surprising that only 11% of optometrists report performing an ocular health assessment as part of the screening, yet almost all test colour vision (which is not health threatening, has not been shown to affect school performance, and has no current treatment options). There is a need to develop an agreed evidence-based battery of tests to be included in systematically organised and monitored children’s vision screenings. This will allow for a consistent approach across vision screenings, maximise the results from the optometrists that are already performing vision screenings and potentially encourage more optometrists to conduct vision screenings, by providing a testing battery for them to follow. The role of both nurses and optometrists in vision screenings also needs to be considered to maximise service delivery. A number of vision screening protocols have been developed and presented in the literature, yet none are specifically recommended by the Optometrists Association Australia for use by optometrists. Subsequently, vision screening programs in Australia remain ad-hoc in nature.

The MCT (Modified Clinical Technique) is a well-known vision screening protocol which was validated by the Orinda study (Bailey, 1998). The tests included in the MCT have been previously presented in Table 2.5-1. In the Orinda study, the MCT had the highest sensitivity (98%) and specificity (99%) in detecting the targeted eye conditions (which were confirmed by a full eye examination) compared with the other screening tests. Distance visual acuity alone, which was one of the screening tests evaluated in the Orinda study, demonstrated poor sensitivity (27%) but relatively good specificity (99%), thus it failed to identify many children who had vision problems (Marshall et al., 2010)

Including a test of refractive error (e.g. retinoscopy) has been shown to markedly improve sensitivity compared with visual acuity screening alone (Bailey,
1998). This is because refractive errors such as hyperopia and some levels of astigmatism may be missed by only testing visual acuity. In addition, screenings that only assess visual acuity have been criticised for not considering visual function at near; arguably the visual skills most strongly related to reading and writing (Ethan & Basch, 2008).

The MCT recommends assessing ocular health as well as quantifying refractive error and phoria measurements, none of which was performed regularly by optometrists or nurses as determined by the current study. This is concerning given that the optometrist skill set includes the ability to detect and diagnose a wide range of ocular conditions and the previously mentioned importance of identifying ocular pathology, hyperopia and binocular vision conditions.

Another vision screening protocol is the Portsea MCT. This is a modified form of the Orinda MCT and was used in a vision screening project between 1980 and 1983 in Portsea, Victoria. The Portsea MCT added tests of fusional vergence, accommodative facility, ocular motility, stereopsis and colour vision to the Orinda battery, on the basis that these tests were more comprehensive in their measurement of visual parameters that had been associated with reduced educational performance (Dwyer, 1983). Even with these additional tests, the Portsea MCT could be performed within 5 – 6 minutes per child (Dwyer, 1983; Walters, 1984a).

The NYSOA screening program also aimed to identify children with a wider range of vision problems compared with the MCT. Reduced visual acuity (distance and near), hyperopia, accommodative infacility, reduced near points of convergence and fusional reserves, colour deficiency, reduced stereoacuity and impaired saccadic eye movements and VMI were targeted in the NYSOA screening battery (Cohen, 1976). Unlike the MCT, the selection of tests in this battery also meant that it could be administered by non-ophthalmically trained screeners. However, it was more time-consuming, and took approximately 15 minutes to complete, compared with 5 – 6 minutes for the MCT (Blum, Peters, Bettman, et al., 1959; Cohen, Lieberman, Stolzberg, & Ritty, 1983).

The balance between sensitivity, specificity and time efficiency is important in developing an optimal screening battery. While increasing the number of tests in a vision screening battery may improve sensitivity, it involves a time penalty and may also reduce specificity. It has, however, been shown in several studies that only
screening visual acuity can miss a large number of children with potentially important vision problems (Bodack, Chung, & Krumholtz, 2010; Marshall et al., 2010).

6.4.3 REFERRAL CRITERIA

The referral criteria for each of the vision tests performed in screenings by nurses and optometrists is presented in Table 6.4-5. This demonstrates that there are a wide range of interpretations regarding what is considered a fail for each test. In addition to the referral criteria listed, two nurses reported referring all children who were screened for an eye examination. This latter process defeats the purpose of the screening process, and is not an effective use of the screener’s time.
Table 6.4-5

Referral criteria used by optometrists and nurses for the different screening tests

<table>
<thead>
<tr>
<th>Referral criteria</th>
<th>Nurses</th>
<th>Optometrists</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vision/refractive error</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;6/6</td>
<td>32%</td>
<td>0%</td>
</tr>
<tr>
<td>&lt;6/7.5</td>
<td>0%</td>
<td>12%</td>
</tr>
<tr>
<td>&lt;6/7.5 or unequal</td>
<td>0%</td>
<td>4%</td>
</tr>
<tr>
<td>&lt;6/9</td>
<td>5%</td>
<td>44%</td>
</tr>
<tr>
<td><strong>Visual acuity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;6/9 or unequal</td>
<td>16%</td>
<td>0%</td>
</tr>
<tr>
<td>&lt;6/12</td>
<td>16%</td>
<td>12%</td>
</tr>
<tr>
<td>&lt;6/12 or unequal</td>
<td>16%</td>
<td>4%</td>
</tr>
<tr>
<td>Unequal vision</td>
<td>16%</td>
<td>0%</td>
</tr>
<tr>
<td>Depends on age</td>
<td>0%</td>
<td>12%</td>
</tr>
<tr>
<td><strong>Hyperopia</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6/7.5 or better with +1.00</td>
<td>0%</td>
<td>25%</td>
</tr>
<tr>
<td>6/6 or better with +1.50</td>
<td>0%</td>
<td>25%</td>
</tr>
<tr>
<td>6/15 or better with +2.00</td>
<td>0%</td>
<td>25%</td>
</tr>
<tr>
<td>Same or better than unaided with +1.00</td>
<td>0%</td>
<td>25%</td>
</tr>
<tr>
<td>Better with +2.00</td>
<td>100%</td>
<td>0%</td>
</tr>
<tr>
<td><strong>Binocular vision</strong></td>
<td>Not performed</td>
<td>Not reported</td>
</tr>
<tr>
<td>Cover test / Hirschberg test</td>
<td>Any movement with cover test</td>
<td>66%</td>
</tr>
<tr>
<td>Any strabismus</td>
<td>33%</td>
<td>24%</td>
</tr>
<tr>
<td>Strabismus, large phorias and/or slow recovering phoria</td>
<td>0%</td>
<td>70%</td>
</tr>
<tr>
<td><strong>Stereoacuity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;60 seconds of arc</td>
<td>Not performed</td>
<td>15%</td>
</tr>
<tr>
<td>&gt;80 seconds of arc</td>
<td>Not performed</td>
<td>30%</td>
</tr>
<tr>
<td>&gt;100 seconds of arc</td>
<td>Not performed</td>
<td>35%</td>
</tr>
<tr>
<td>&gt;120 seconds of arc</td>
<td>Not performed</td>
<td>5%</td>
</tr>
<tr>
<td>&gt;200 seconds of arc</td>
<td>Not performed</td>
<td>10%</td>
</tr>
<tr>
<td>&gt;300 seconds of arc</td>
<td>Not performed</td>
<td>5%</td>
</tr>
<tr>
<td><strong>Motility</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Any abnormality</td>
<td>Not reported</td>
<td>100%</td>
</tr>
<tr>
<td><strong>Near point of convergence</strong></td>
<td>&gt;5cm</td>
<td>17%</td>
</tr>
<tr>
<td>&gt;10cm</td>
<td>Not reported</td>
<td>66%</td>
</tr>
<tr>
<td>&gt;15cm</td>
<td>Not reported</td>
<td>17%</td>
</tr>
<tr>
<td><strong>Phoria measurement</strong></td>
<td>≥3esophoria or ≥6 exophoria as a fail</td>
<td>Not performed</td>
</tr>
<tr>
<td><strong>Colour vision (Ishihara)</strong></td>
<td>1 error</td>
<td>13%</td>
</tr>
<tr>
<td>2 errors</td>
<td>Not performed</td>
<td>19%</td>
</tr>
<tr>
<td>3 errors</td>
<td>Not performed</td>
<td>63%</td>
</tr>
<tr>
<td>4 errors</td>
<td>Not performed</td>
<td>6%</td>
</tr>
<tr>
<td><strong>Ocular health</strong></td>
<td>Any abnormality</td>
<td>Not performed</td>
</tr>
</tbody>
</table>
Little agreement exists between optometrists in terms of referral criteria. This is not surprising given that very little consistency also existed between optometrist responses relating to the tests included in children’s vision screenings (see Table 6.4-4). The current vision screening protocols selected and conducted in Queensland by optometrists showed no clear adherence to any known protocols.

Visual acuity and stereoacuity are the only two tests that were performed by all optometrists, yet the responses relating to the referral criteria for these tests showed the greatest variability. Three of the 27 optometrists considered age as a factor when reporting the referral criteria used for visual acuity testing. Given that the mean visual acuity in children differs by one line between six year old and twelve year old children (Robaei, Huynh, Kifley, & Mitchell, 2006; Robaei et al., 2005) it follows that the expected visual acuity in a vision screening setting would differ by age also.

The referral criterion for visual acuity for primary school children in the Modified Clinical Technique (MCT) was 6/12 or worse (Blum, Peters, Betman, et al., 1959). This criteria is considered appropriate for younger school children, however given the mean visual acuity in twelve year old children is 6/6 (compared with 6/7.5 in six year old children) it is suggested that the acuity criterion should also be adjusted by one line (6/9 or worse). In addition, the MCT does not consider unequal acuity between the two eyes, which can be an important sign of amblyopia. A difference in acuity of two lines or more has been used in a number of paediatric vision screenings (Miller, Harvey, & Dobson, 1999; Oliver & Nawratzki, 1971). Based on findings in the literature, a referral criterion of 6/12 or worse for children in the younger year levels at primary school, and 6/9 or worse for the older year levels, or a difference in acuity between the two eyes of two lines or more, is considered an appropriate visual acuity referral criterion for Australian children.

The other screening test performed by all optometrists was the stereoacuity test. There are a number of commercially available stereoacuity tests, of which the Titmus, Randot, Frisby, Lang II and TNO are some examples. Published pass-fail criteria for each test are presented in Table 6.4-6 (Ohlsson, Villarreal, Cavazos, Sjostrom, & Sjostrand, 2001).
Table 6.4-6
Pass/fail criteria for different stereoacuity tests

<table>
<thead>
<tr>
<th>Stereoacuity test</th>
<th>Pass/fail criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Titmus</td>
<td>100”</td>
</tr>
<tr>
<td>Randot</td>
<td>70”</td>
</tr>
<tr>
<td>Frisby</td>
<td>300”</td>
</tr>
<tr>
<td>Lang II</td>
<td>Non-perception of any of the figures</td>
</tr>
<tr>
<td>TNO</td>
<td>240”</td>
</tr>
</tbody>
</table>

It is evident from this table that the fail threshold for stereoacuity varies depending on the test. This would explain the variation in responses by optometrists in the survey given the wide range of tests used to measure stereoacuity.

Stereoacuity alone has been reported as an inadequate screening test in preschool and primary school children (Ohlsson et al., 2001; Vision in Preschoolers (VIP) Study Group, 2003). The ability of the five stereoacuity tests in Table 6.4-6 to screen for strabismus and/or amblyopia in a study on 12 and 13 year old children was shown to be inadequate given that only eight of the 60 children with strabismus and/or amblyopia were identified by all five tests, and 25 of the 60 were not identified by any (Ohlsson et al., 2001). The authors concluded that because the results from children with strabismus and/or amblyopia as well as children with normal binocular function were variable, the ability of the tests to differentiate between normal and abnormal responses was limited. The findings from their study are relevant to vision screening programs currently being performed in Queensland, given that all optometrists reported measuring stereoacuity. A re-evaluation of the tests incorporated in vision screening programs as well as setting clear referral criteria is required to ensure optimal use of the screener’s time.

Although a more uniform approach appears to be followed by nurses (compared with optometrists) regarding the selection of tests performed in a screening, different interpretations of the referral criteria still exist between nurses. This is despite recommended referral criteria being published in Queensland Health
Child and Youth Health Practice (CYHP) manual alongside each test (Queensland Health, 2007), see Table 6.4-7.

Table 6.4-7

*Vision screening tests and referral criteria – Queensland Health Child and Youth Health Practice Manual*

<table>
<thead>
<tr>
<th>Test type</th>
<th>Referral criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual acuity (6m and monocularly)</td>
<td>6/12 or worse in either eye or a difference of two lines between the eyes (6/15 or worse in either eye for children less than four years old)</td>
</tr>
<tr>
<td>• Lea symbols for preliterate</td>
<td></td>
</tr>
<tr>
<td>• HOTV for children older than three and a half years with confusion bars</td>
<td></td>
</tr>
<tr>
<td>• Linear STYCAR 7 letter chart</td>
<td></td>
</tr>
<tr>
<td>with or without keycard for year one students</td>
<td></td>
</tr>
<tr>
<td>Cover test (unilateral and alternating)</td>
<td>Any unequal movement of eyes is referred</td>
</tr>
<tr>
<td>Hirschberg test</td>
<td>Any unequal corneal light reflex is referred</td>
</tr>
</tbody>
</table>

The referral criterion for visual acuity specified in the CYHP manual varies depending on the age of the child, and it also includes a provision for a difference in acuity between the two eyes. The nurse survey in this study related to children screened who were aged between four and seven years, according to the CYHP manual the referral criterion should have been 6/12 or worse in either eye (<6/9) or two lines difference. However, only 16% of nurses reported using this criterion, see Table 6.4-5. The most common referral criterion was less than 6/6. This criteria is thus likely to result in many false positives given that the mean visual acuity in six year old children is 6/7.5 (Robaei et al., 2005)

The referral criterion for the cover test recommended in the CYHP manual is not ideal, as it recommends referral of any unequal movement of eyes. In the case of large phorias, slow recovering phorias and some alternating strabismus, an equal movement of the eyes would be observed, not an unequal movement – and would
therefore not be referred by this criterion resulting in a high number of false negatives. Furthermore, results from the current study show that two thirds of nurses performing the cover test referred any movement (despite the CYHP manual recommending otherwise). This has the potential to result in a large number of false positives, as exophorias at near (with a quick recovery) would be referred despite often being a normal finding. These two different referral criteria suggest that the nurses, or the personnel writing the Queensland Health practice manual, do not necessarily understand the purpose of the cover test.

Similar findings have been reported in the past, where an evaluation of the Queensland School Health Service Vision Screening Program showed that approximately half the number of strabismus cases were not detected by nurses performing a cover test (MacFarlane et al., 1987). The nurse survey showed that nurses play a critical role in vision screenings in Queensland, as seen by the number of sites that are actively involved in screenings across Queensland. However, the capacity of nurses to perform and interpret vision tests beyond a visual acuity test was not demonstrated in this study. Better consideration of the most appropriate vision screening tests to be performed by nurses is required, as well as adequate training for these tests. This will improve the overall efficiency of screenings performed by this group.

This study has also shown that much variation exists in the provision of children’s vision screening programs across Queensland. Amongst those that do take place, the vision tests included in the screening and their corresponding referral criterion varied greatly between optometrists and between nurses; and in the case of nurses, the provided guidelines were not being followed. Existing screening programs do not appear to be meeting the needs of Queensland children - Indigenous or non-Indigenous - as common paediatric eye conditions are not routinely screened for, nor is there screening for eye conditions that have been associated with reduced educational outcomes, and referral criteria vary widely for tests that are being used.

For a screening program to be effective, the following guidelines need to be adhered to (Wilson & Jungner, 1968):

- The condition being screened is common;
- The condition represents a significant health problem;
Based on these criteria, children’s vision screening programs have the potential to be effective. However, a more coordinated approach is required to ensure existing resources are used efficiently and common paediatric vision conditions are targeted and detected in the most effective manner.

6.4.4 VISION SCREENING MODEL

Based upon the results of this study, the author proposed a model that would coordinate and oversee the provision of children’s vision screenings. This model would address the coverage of vision screening services across Queensland and develop the most appropriate vision screening protocol. It is anticipated that both optometrists and nurses would play a critical role in this model. A schematic of this vision screening service delivery model is presented in Figure 6.4-1.
Figure 6.4-1. Schematic of proposed vision screening service delivery model
**Provision of children’s vision screenings across Queensland**

Under this model, regions in Queensland that are underserviced with respect to children’s vision screenings would be identified. This will involve expanding on the findings of the current study as well as directly contacting schools and kindergartens, to allow a comprehensive identification of those areas at most need.

The second step will be to gain support for this vision screening service delivery model from both optometrists and nurses. This would need to be done by directly contacting optometrists and nurses currently providing vision screenings or interested in providing screenings in the future (with the assistance of relevant professional bodies) and allocate their services to identified schools and kindergartens. It is proposed that this would be managed via an online central booking system established at a site with relevant staff experience and interest, such as Queensland University of Technology (QUT). The booking system would enable vision screening services to be requested directly by kindergartens and primary schools, with local optometrists and nurses being able to accept the request. It should also allow for ongoing expansion as new kindergartens, schools and providers are recruited. The most appropriate method to create awareness of the central booking service for kindergartens, primary schools and optometrists and nurses would need to be determined as well as appropriate funding for the development and maintenance of the booking database.

It is envisaged that when a kindergarten or primary school requests a vision screening, a local optometrist would be approached to provide this service in the first instance. In the event that no optometry service is available, nurses would be contacted to meet this need. In some cases, for example in rural areas of Queensland, where optometry services are sparse, nurses would be the primary point of contact for many kindergartens and primary schools.

This model will result in the documentation and management of vision screening services provided by optometrists and nurses beyond the ad hoc, unmeasured and inconsistent manner in which it currently occurs. Regular and sustained visits by local optometrists and nurses to kindergartens and primary schools across Queensland, as well as increasing the coverage and minimising overlap of existing vision screening programs, would be important predicted outcomes of this proposed program.
**Vision screening protocols for optometrists and nurses**

In addition to addressing the provision of vision screening services across Queensland, standardised vision screening protocols that can be employed by optometrists and nurses need to be developed as part of the model. Different vision screening protocols would be required for optometrists and nurses, as optometrists can perform a wider range of tests in a single screening because they have more training and experience with vision testing compared to nurses. Subsequently, it is predicted that the vision screenings performed by optometrists will have fewer false positive and false negative outcomes compared with nurses. Nevertheless, an optimal vision screening battery for both optometrists and nurses is required to ensure the most effective use of resources and existing skills for each profession, as well as enabling maximum coverage across Queensland to take place.

Standardised vision screening protocols would be developed after consideration of the prevalence of paediatric vision conditions in Australian children as well as the possible impact such conditions have on educational outcomes. The most appropriate set of vision tests for detecting these conditions as well as suitable referral criteria to minimise false positives and negatives would be determined; with computerised vision screeners being potentially considered as part of this process. Factors to be considered are the suitability of the tests to be performed by nurses and optometrists in a screening setting at a kindergarten or school, the age group of the children to be screened in terms of referral criteria and understanding of the test and the number of tests to be included in the screening. This approach should minimise the time taken to assess each child, but maximise screening accuracy outcomes.

Training material may be required for specific tests, particularly if they are not commonly performed by nurses. A training module and follow-up training would be useful for both optometrists and nurses, to ensure screening tests are administered in a standardised manner. This training material as well as additional vision screening material (standardised guidelines, results sheets, consent forms, parent reports) would be created and provided through the central location at QUT. Support for newly recruited service providers regarding initial set up of mobile equipment and administrative requirements would also be made available. This approach is designed to facilitate the provision and uptake of screening services by optometrists and nurses for kindergartens and primary schools.
The proposed model has the potential to permanently improve paediatric vision screenings conducted in Queensland as well as more broadly within Australia. Eventual adoption of the model nationally in an ongoing manner, under the direction of the professional bodies that represent optometrists and nurses would enable a standardised, consistent and measurable approach to children’s vision screenings throughout all states and territories. At this stage, ensuring there is adequate funding for this service delivery model is important to ensure it is sustainable. Factors to consider are the ongoing maintenance of the central database, costs associated with supplying training and resource material to health professionals as well as providing an incentive for optometrists to leave their own practice to perform a vision screening (as currently there is no financial reimbursement available to optometrists). The model may also have applicability in other countries and for other allied health professions.

The success of the model should be measured in terms of the following outcomes:

- The increase in kindergartens and primary schools who are, a) identified and, b) have received vision screening services since the commencement of the program;
- The increase in optometrists and nurses who deliver vision screenings via the central administration system;
- The establishment of a screening kit providing a comprehensive screening battery available to optometrists and nurses involved in this program;
- Increase in the number of children utilising existing optometry services as a result of vision screening referrals;
- Reduction in the prevalence of undetected eye conditions in Queensland children (in the long term).

The final outcome also requires an adequate referral pathway following detection at a screening. Coordination with and support from local optometrists, not just those involved with screenings, would be needed to diagnose and manage the conditions detected at vision screenings.
In summary, the current study has demonstrated that children’s vision screening services in Queensland are irregularly distributed and ad-hoc in nature. Furthermore, duplication of services between optometrists and nurses may be taking place, while other regions are likely to be missing out entirely. Queensland children will benefit from improved cohesion and communication between optometrists and nurses to enable an equitable provision of validated screening services. The model proposed in this section aims to provide a more coordinated approach to children’s vision screenings. Importantly, this aims to provide the best opportunity for early detection and intervention for a range of important paediatric vision problems for Indigenous and non-Indigenous children, particularly those related to academic outcomes.
Chapter 7: Conclusions

The gap in reading and numeracy between Australian Indigenous and non-Indigenous children is well documented. While a number of vision conditions have been associated with reduced reading ability, uncorrected hyperopia, binocular vision disorders and impaired visual information processing skills, the prevalence of these conditions and other paediatric vision conditions is unknown in Australian Indigenous children. Refractive error, strabismus, colour vision deficiency, accommodation and/or vergence disorders and visual information processing ability, all of which are routinely screened and/or tested in children’s eye examinations in the wider population, have not been investigated in detail in this group. Understanding the prevalence of these conditions will assist in ensuring adequate resources are available for detecting and managing these conditions in Indigenous children. Vision screenings are one method for detecting potential vision problems in this group. However, in Australia, there is little information regarding the coverage and nature of children’s vision screenings. Understanding the extent and content of vision screenings will ensure there are no regions currently under- or over-serviced, and that vision screenings are targeting conditions relevant to both Australian Indigenous and non-Indigenous children.

The main aim of the current research was to characterise the visual profile of Queensland Indigenous children and to determine the link between vision conditions and reading ability in this population. A secondary aim was to evaluate vision screening services in Queensland in terms of their coverage, and ability to detect conditions common in this group. Prior to the main study, it was necessary to undertake a preliminary study to determine what would be the most appropriate method for measuring refractive error in school children in a field-based setting. The results from the preliminary study were used to determine which refractive error measurement technique was selected for the main study.

In the preliminary study, refractive error was measured on twenty five school children with both retinoscopy and autorefraction under cycloplegic and non-cycloplegic conditions. Findings from this study indicated that cycloplegic
retinoscopy is the most appropriate method for measuring refractive error in children. This is due to the ability of cycloplegia to control accommodation compared to non-cycloplegic methods such as extended optical fogging, as well as the repeatability of the technique. When performed by an experienced optometrist, retinoscopy was more repeatable than autorefraction under both cycloplegic and non-cycloplegic conditions. Cycloplegic retinoscopy was also more repeatable than non-cycloplegic retinoscopy.

In the main study, 595 Indigenous and non-Indigenous children were recruited. The large number of children that participated is a strength of the current study, as it is the first study of this size conducted in Queensland to have measured such a range of visual parameters. Children from nine Queensland primary schools participated. Schools were selected because they had a high proportion of Indigenous children attending their school; children from Years 1, 2, 6 and 7 participated in the study. These year levels were chosen because they represent two different stages of primary school. Children in Years 1 and 2 are in the ‘learning to read’ stage where as children in Years 6 and 7 are in the ‘reading to learn’ stage. These different stages present different demands on the visual system, and subsequently, deficiencies or delays in some vision parameters, may affect reading outcomes differently. A comprehensive battery of vision testing including assessment of visual acuity, refractive error (measured with cycloplegic retinoscopy), binocular vision testing (near point of convergence, fusional vergences, accommodating facility, horizontal heterophoria, stereoacuity), colour vision, RAN, VMI and reading ability was performed.

Results from this study demonstrated that Indigenous children had significantly less refractive error (9.6% compared with 16.1%) and strabismus (none compared with 3.0%) than their non-Indigenous peers. CI however, was twice as common in Indigenous children (10.3% compared with 5.2%); reduced RAN and/or VMI was also more common in Indigenous children. Reduced RAN and VMI were defined as a score lower than one standard deviation below the mean. Using this definition, 67.4% of Indigenous children had a reduced RAN, compared with 58.6% of non-Indigenous children; and 28.1% of Indigenous children had a reduced VMI, compared with 16.3% of non-Indigenous children. Both of these differences (RAN and VMI) were significant. This might be particularly important given the
association between delayed visual information processing skills and reduced reading ability.

Reading outcomes were also significantly different between the groups with Indigenous children scoring significantly lower in reading accuracy in both age groups and Indigenous children in the younger age group also scoring significantly lower in reading comprehension. Mean reading accuracy percentile scores for Indigenous children in the younger and older age groups were 29.5 and 32.6 respectively, this compared with mean percentile scores of 40.0 and 42.0 in non-Indigenous children, in the younger and older age groups. The mean reading comprehension percentile score was 21.4 in Indigenous children in the young age group, compared with 37.3 in non-Indigenous children of the same age.

Reduced RAN and VMI skills were significantly associated with reduced reading ability in both Indigenous and non-Indigenous children in both age groups. As much as 28% and 31% of the variation in reading accuracy in the younger age group was explained by either RAN and/or VMI in Indigenous and non-Indigenous children. This finding agrees with other studies that have shown RAN and VMI to be good predictors of reading outcomes. Importantly, the current study is the first to investigate this relationship in Queensland Indigenous and non-Indigenous children. This is of particular importance given the known gap in reading outcomes between Australian Indigenous and non-Indigenous children; and that we have demonstrated for the first time that reduced RAN and VMI were more common in Indigenous children. Further research is required, however, to determine whether reduced RAN and VMI are causative factors in reduced reading ability, and whether a subsequent intervention to improve these abilities might also improve reading outcomes.

This research also adds substantially to the existing knowledge on Queensland Indigenous children’s vision as only a limited number of other studies have measured visual function in Indigenous children (Mann & Rountree, 1968; Paterson et al., 1998; Stocks et al., 1997; Taylor, 1980; Taylor et al., 2009). Specifically, this study is the first to comprehensively investigate refractive error (measured with a cycloplegic refraction), binocular vision conditions (strabismus and accommodation and/or vergence disorders), visual information processing skills (VMI and RAN) and colour vision deficiency in this group. Understanding the prevalence of these vision
conditions in Indigenous children is important because it will assist in ensuring adequate resources are available for detecting and managing the conditions.

Vision screenings are one method for detecting potential vision problems in this group. However, in Australia, there is little information regarding the coverage and nature of children’s vision screenings. A secondary aim of this research was to evaluate existing vision screening services available to Queensland school children. Firstly, in terms of their coverage across the state (by nurses and optometrists) and secondly in terms of their ability to detect conditions common to Indigenous and non-Indigenous children, as well as conditions that have been associated with reduced reading performance.

A comprehensive literature review was performed and established that there is no universally agreed policy or screening strategy with regards to vision screening services in Australia. This is most likely a consequence of the lack of evidence supporting the benefits of screening as well as inconsistent levels of support from relevant authorities. Consequently, the provision of vision screenings is poorly coordinated and irregularly distributed across Australia through multiple health professions. The findings of this review are supported in this study, where it was demonstrated that a number of health service districts within Queensland have a very low provision of children’s vision screening services. Furthermore, there is no uniform battery of tests used in children’s vision screenings by nurses or optometrists. While the majority of screenings measured visual acuity and screened for strabismus, the specific tests used varied between survey respondents. A large number of optometrists also included colour vision and stereoacuity tests as part of the screening. Additional tests of binocular vision, visual information processing and/or ocular health were performed only by a small number of nurses and optometrists. Little agreement also exists between optometrists and nurses in terms of referral criteria and in many cases the referral criteria were not appropriate and demonstrated a lack of understanding of the screening test. Using the cover test as an example, a number of nurses reported referring either any movement observed or any unequal movement. Neither of these referral criteria would adequately detect all strabismus, and in the case of referring any movement, a high percentage of false negatives would result, due to the referral of all heterophorias.
Collectively, there are a number of implications from this research’s findings. Primarily, this study is the first to report the prevalence of refractive error, strabismus, accommodation and/or vergence disorders, delayed visual information processing skills (RAN and VMI) and colour vision deficiency in Australian Indigenous children. Understanding which vision conditions are more common in Indigenous children will assist eye care practitioners in their assessment of this group, particularly if the eye conditions have been associated with educational outcomes in the wider population. CI was found to be twice as common in Indigenous children, thus eye care provision to these children needs to incorporate appropriate testing to allow for classification of CI, such as measurements of near point of convergence, horizontal phoria and fusional vergence range.

Secondly, knowing what vision conditions are associated with reading ability will also benefit eye care practitioners with their assessment and management of children who are having difficulty with reading. The current study showed that a reduction in the visual information processing skills of RAN and VMI was associated with reduced reading ability. RAN describes the ability to transfer visual information to verbal information at speed, and therefore may play an important role in the task of reading. In addition to reading, adequate visual information processing skills are necessary for a number of school tasks. VMI is required for activities such as writing and drawing, which need controlled visually guided fine motor skills. While numeracy tasks may place a demand on visual analysis skills to differentiate between letters, numbers and shapes, as well as adequate visual memory skills to recall previously presented visual information. Consequently, visual information processing skills should be examined, or at a minimum considered, by optometrists when examining children who are underachieving academically.

An area of future research that would be beneficial to this group is to establish whether other visual information processing skills are associated with additional academic outcomes, such as writing and numeracy, in Indigenous and non-Indigenous children. As well, further research could determine whether an intervention program specifically targeting VMI and RAN skills in children with reduced reading scores would have a positive effect on reading outcomes and/or other academic outcomes. This needs to be tested specifically in Indigenous children since the overall lower reading scores in this group (as well as writing and numeracy
skills as determined in recent nation-wide testing) suggests multiple causative factors may be at play. Subsequently, visual information processing skill intervention outcomes for the wider population may not necessarily represent what would occur in Indigenous children.

Finally, screening programmes need to be better coordinated. This study identified many regions in Queensland that were very underserviced in terms of the provision of vision screenings. Improving the coordination of existing screening programs is required to make certain that no regions remain without service, as well as to ensure duplication of existing services does not occur.

A standardised screening protocol also needs to be developed so that appropriate tests are included in the screenings to ensure that conditions common to Indigenous and non-Indigenous children will be detected. As it stands, only visual acuity testing and strabismus assessment are performed in many vision screenings, which means that many Indigenous children will in fact pass the screening, given the low prevalence of vision impairment, refractive error and strabismus in this group. However, testing for CI is also important given that it is twice as common in Indigenous children and has the potential to cause asthenopia and affect concentration span. Furthermore, hyperopia, which is the most common refractive error in Australian Indigenous and non-Indigenous children and has also been associated with reduced reading outcomes in the wider population, may not be detected in a vision screening, if reduced visual acuity is the only test used to screen for this condition. Additional tests such as the plus lens hyperopia test, or a refraction technique would be required to detect a greater number of children with hyperopia. The advantages and disadvantages of screening visual information processing skills in Australian Indigenous and non-Indigenous children also needs to be considered when developing the screening protocol, given the findings of the current study that have shown that reduced RAN and VMI were associated with poorer reading outcomes, as well as being significantly more common in Indigenous children.

A limitation of the current study is that it only included children attending schools in low socioeconomic areas. This was because schools in these areas had a higher proportion of Indigenous children attending compared with schools in high socioeconomic areas. This affects the generalisability of the results. Firstly, the
prevalence of some vision conditions (for example vision impairment resulting from uncorrected refractive error, and delayed visual information processing skills) have been shown to vary depending on the socioeconomic background of the group. It is possible that the prevalence of these conditions would be different in Indigenous children from different socioeconomic backgrounds. Secondly, low socioeconomic background, Indigenous background, language background other than English, and living in rural areas have all been identified as risk factors for reduced reading outcomes in Australian children (Gonski et al., 2011). More of these factors are present in children from low socioeconomic areas and may have a greater effect on reading outcomes compared with vision conditions; this was evidenced in the current study, by the mean reading percentile scores being below the 50th percentile for both Indigenous and non-Indigenous children. The generalisability of the results relating to reading ability to vision condition in the current study is therefore potentially limited; different findings may have resulted if the study were repeated on children attending schools from high socioeconomic areas and/or children with higher reading scores.

In conclusion, this study was the first to comprehensively assess a range of vision characteristics in a large group of Indigenous and non-Indigenous children. The prevalence of a number of common paediatric vision conditions in Australian Indigenous children that was not previously known has been reported. The main findings were that Indigenous children have less vision impairment, refractive error and strabismus; yet CI is twice as common. This is important given that accommodation and/or vergence disorders have been associated with educational outcomes, and CI can result in asthenopia and reduced concentration. The effect of vision conditions on reading was also investigated, with RAN and VMI being associated with reduced reading ability in Indigenous and non-Indigenous children. This study is also the first to attempt to document the coverage of existing vision screening programs across Queensland by nurses and optometrists; as well as the battery of tests performed in screenings and the referral criteria. Findings from the study have indicated that current vision screening programs need to be more coordinated if they are to detect paediatric vision conditions common in Indigenous and non-Indigenous children.
Two areas of future work have emerged from this research. Firstly, further investigation of the functional effect of CI on educational outcomes (in addition to reading outcomes) in Indigenous children is warranted, as well its association with asthenopia, concentration span and fatigue. Measuring symptom levels with a standardised symptom survey would be one method of determining the association between CI and these factors. Similarly, the functional effect of reduced RAN and VMI on other educational outcomes (such as writing, spelling and numeracy) could be assessed in Indigenous children. This would help determine the importance and urgency of developing appropriate interventions and management strategies targeting these conditions in this group.

Secondly, more work is required to develop the model that has been proposed for nurses and optometrists to provide a more standardised approach to children’s vision screenings. Further work is required to develop an evidence-based vision screening protocol appropriate for use by optometrists and nurses which can be administered at schools or health centres. Implementation of the screening protocol would require the support of optometrists, nurses, schools and kindergartens; liaison with the respective professional bodies will also be required to initiate communication to all interested groups.

Application of the proposed vision screening service delivery model would improve the coverage of vision screenings across Queensland, as well as provide vision screeners the resources and training to undertake a standardised vision screening protocol that has been developed specifically for Australian school children. Importantly, vision conditions relevant to both Indigenous and non-Indigenous children will be detected earlier which has the potential to significantly reduce the negative impact untreated eye conditions can have on a child’s reading ability.
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Appendices 191


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APPENDIX A: REVIEW OF GUIDELINES FOR CHILDREN’S VISION SCREENINGS

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Abstract:

The aim of children’s vision screenings is to detect vision problems that are common in this age category through valid and reliable tests. Nevertheless, the cost effectiveness of paediatric vision screenings, the nature of the tests included in the screening batteries and the ideal screening age has been the cause of much debate in Australia and worldwide. The purpose of this review was to therefore report on the current practice of children’s vision screenings in Australia and other countries, as well as to evaluate the evidence for and against the provision of such screenings. This was undertaken through a detailed investigation of peer-reviewed publications on this topic.

The current review demonstrates that there is no agreed vision screening protocol for children in Australia. This appears to be a result of the lack of strong evidence supporting the benefit of such screenings. Whilst amblyopia, strabismus and, to a lesser extent refractive error, are targeted by many screening programs during pre-school and at school entry – there is less agreement regarding the value of screening for other visual conditions such as accommodation and/or vergence disorders, ocular health problems and refractive errors that are less likely to reduce distance visual acuity. In addition, in Australia, little agreement exists in the frequency and coverage of screening programs between states and territories, and the screening programs that are offered are ad hoc and poorly documented.

Australian children stand to benefit from improved cohesion and communication between jurisdictions and health professionals to enable an equitable provision of validated vision screening services that have the best chance of early detection and intervention for a range of paediatric visual problems.
The purpose of paediatric vision screenings is to detect children who have, or are at risk of developing, specific age-relevant vision problems. It is important to identify vision conditions in a timely manner as many common vision problems can be managed effectively once identified. In a number of these cases – for example retinoblastoma or amblyopia – early detection reduces morbidity and facilitates successful treatment outcomes (Marshall et al., 2010). Availability of valid and reliable test batteries is fundamental to this process being successful. There is ongoing debate, however, with regards to the cost effectiveness of paediatric vision screenings, the precise tests that should be included in screening batteries, and the ideal age for administration of these batteries. This review explores the history of paediatric vision screening, outlines current practice in Australia, and evaluates the evidence base underlying the provision of such screening programs.

Vision conditions that are screened for in childhood include amblyopia and its risk factors (strabismus, anisometropia or congenital cataract), refractive error, colour vision defects (CVD) and ocular pathology (for example, congenital glaucoma or retinoblastoma), (Cummings, 1996; Ethan & Basch, 2008; Stewart-Brown & Haslum, 1988; Tengtrisorn et al., 2009; Thomson & Evans, 1999). Colour vision assessment is, however, not always included in screening batteries, on the basis that congenital CVD is untreatable and that the role of impaired colour vision in the learning process has not yet been well-established (Oberklaid et al., 2002). Screening for binocular vision dysfunction and hyperopia is better accepted as there is some evidence to support an association with impaired academic performance (Godts et al., 1999; Krumholtz, 2000; Reed et al., 2004; Rosner & Rosner, 1997; Stifter et al., 2005a).

In 2009 an Australian group, under the auspices of the National Children’s Vision Screening Project (NCVSP), undertook a systematic literature review of the effectiveness of vision screening programs. This literature review concluded that the ideal age for screening the vision of children was between 18 months and 5 years, in addition to a standard neonatal check (Morcos & Wright, 2009). The review further concluded that screening from ages 8 to 10 years old and from 13 to 15 years old was not indicated, as there was insufficient incidence of previously unrecognised visual impairment in those age groups. The NCVSP subsequently established an expert Project Advisory Group (PAG) which recommended that vision assessment be
undertaken at birth, between 3 and 6 months, and at four years of age (one year prior to school commencement). This recommendation was made despite a lack of evidence from the literature supporting vision screening of children aged 3 – 6 months, where the PAG considered that screening of this age group was important, to ensure that any vision problems missed at the neonatal check could be detected. The PAG also recommended visual screening at four years of age rather than between the ages of 18 months and 3.5 years, recommended by the initial review, on the basis of the decreased ability of children to complete the screening procedures effectively. Instead, a screening at age 4 years was recommended.

The NCVSP review concentrated only on vision screening programs that targeted reduced visual acuity, strabismus, congenital cataract and congenital glaucoma. However, conditions such as uncorrected hyperopia and binocular vision dysfunction have been shown to have an association with reduced academic ability (Godts et al., 1999; Krumholtz, 2000; Palomo-Alvarez & Puell, 2008). These visual conditions were not included in the NCVSP review which is a limitation to the NCVSP’s final recommendations, as it can be argued that not all visual conditions relevant to children were considered. Indeed, the optimal age group at which these conditions would be detectable via vision screening may be different from those recommended by the PAG.

Other authors have disagreed with the NCVSP’s recommendations regarding the optimal age for children to be screened. Whilst it has been suggested that improved visual acuity outcomes are achieved with earlier treatment of amblyopia (Williams, Northstone, Harrad, Sparrow, & Harvey, 2003), one study has shown that the age at which amblyopia treatment is instigated does not affect the final outcome, provided the child is aged 7 years old or less (Pediatric Eye Disease Investigator Group, 2002). This suggests that the optimum age of treatment for amblyopia is not as critical as was previously believed. These findings add to the debate regarding the most effective age for screening children for amblyopia and its risk factors. It has also been suggested that while screening at preschool may detect amblyopia earlier, screening in the first year of school achieves a higher coverage because of compulsory school attendance, and provides a more time-efficient way to screen all children within a geographical region (Hall & Stewart-Brown, 1998; Williamson et al., 1995).
DEVELOPMENT OF VISION SCREENING PROTOCOLS

The US-based Orinda study pioneered the systematic investigation of specific vision parameters that comprise an effective paediatric vision screening battery. This involved a three year study of primary school children from the Orinda School District in California, commencing in 1954. Eight screening methods were administered to school children, as well as a complete clinical eye examination. Optometrists and ophthalmologists from the Orinda study also identified a number of specific visual and ocular problems that should be prioritised for screening. These included reduced visual acuity, a range of refractive errors (hyperopia, myopia, astigmatism and anisometropia), binocular coordination disorders at distance and near (strabismus and significant heterophoria) and evidence of any ocular pathology (Blum, Peters, Betman, et al., 1959).

What has since become known as the Modified Clinical Technique (MCT) provided the least number of under-referrals (highest sensitivity) and over-referrals (highest specificity). As such, it was the first vision screening protocol to be validated and is often considered to be the gold standard paediatric screening protocol. Tests comprising the MCT are presented in Table 1. Figure 1 further explains the statistical concepts of sensitivity, specificity and predictive values using the Ishihara colour vision test as an example; these metrics are commonly used to compare the effectiveness of individual tests or screening batteries (Altman & Bland, 1994).

The MCT had an 11.5% mean referral rate, compared with 5.8% mean referral rate based on visual acuity alone (Marshall et al., 2010). In the Orinda study, the MCT battery correctly classified almost all children with extremely high sensitivity (98%), specificity (99%) and predictive values (positive predictive value of 0.90 and negative predictive value of 0.99). Distance visual acuity alone demonstrated poor sensitivity (27%) but relatively good specificity (99%) – and failed to identify many children who had vision problems, although it did not tend to result in over-referrals for those who had normal healthy eyes and good vision (Marshall et al., 2010).

Including a test of refractive error (e.g. retinoscopy) markedly improved sensitivity compared with visual acuity screening on its own (Bailey, 1998). Indeed, refractive errors such as hyperopia and some levels of astigmatism may be missed by visual acuity testing. In addition, screenings that only measure distance visual acuity have
been criticised for not measuring visual function at near; arguably the visual skills that are most strongly related to reading and writing (Ethan & Basch, 2008).

A disadvantage of the MCT is that it requires optometrists or ophthalmologists to assess refractive error (with retinoscopy) and to screen for ocular disorders; it therefore cannot be administered by non-ophthalmically trained vision screeners (Paech, 2010). Consequently, the expediency of the Orinda MCT as a screening tool has been questioned (Paech, 2010; Rice, 1959). Furthermore, the remarkably high sensitivity and specificity reported by the MCT from Orinda has not been replicated in subsequent studies that have also used the MCT battery (Paech, 2010). In two other studies the positive predictive values obtained were 0.69 (Bailey, 1998) and 0.52 – much lower than those found at Orinda (Marsh-Tootle et al., 1994). In the original Orinda MCT, the decision on whether a child passed or failed the MCT was based on assessments by two independent optometrists after consideration of the results from the series of tests. However, the opinion of an additional four vision care experts was sought in cases of disagreement (Paech, 2010). The lack of a definitive pass/fail criterion for the MCT in the Orinda study may explain why the extremely high sensitivity and specificity has not been replicated. Importantly, most vision screenings do not have the luxury of a sizeable “expert panel” to consult prior to making referral decisions.

A modified form of the Orinda MCT (Portsea MCT) was included in a vision screening project between 1980 and 1983 that was part of a larger public health initiative at Portsea in Victoria, Australia. Prior to this, from the late 1940s, optometrists had been performing ad hoc vision tests on approximately two thousand school children each year at this location. The Portsea MCT added fusional vergence, accommodative facility, ocular motility, stereopsis and colour vision tests to the Orinda battery, on the basis that these tests were more comprehensive in their measurement of visual parameters ostensibly associated with reduced school performance (Dwyer, 1983).

Even with the additional tests, the Portsea MCT could be performed within 5 – 6 minutes per child (Dwyer, 1983; Walters, 1984b). Referral rates from the Portsea study were 17.7% (classified as “unsatisfactory”) and 10.4% (classified as “borderline”); this was comparable to referral rates from a NSW vision screening
performed on a similar cross-section of children (Amigo, McCarthy, & Pye, 1976), as well as to other screenings that used the Orinda MCT at that time.

The NYSOA (New York State Optometric Association) screening battery was developed to identify children with a wider range of visual problems (Bodack et al., 2010). The sensitivity and specificity of the NYSOA battery were 72% and 65% respectively. The NYSOA battery targeted reduced distance and near visual acuity, hyperopia greater than two dioptres, and problems with accommodative facility, near point of convergence, fusional reserves, colour vision, stereopsis, saccadic eye movements and VMI (Cohen et al., 1983). Unlike the Orinda MCT, the selection of tests included in the NYSOA battery allowed administration by non-ophthalmically trained screeners. However, it was more time consuming than the MCT (Bodack et al., 2010); the Orinda MCT took between 5 – 6 minutes per child, compared with 15 minutes for the NYSOA battery (Blum, Peters, Bettman, et al., 1959; Cohen et al., 1983).

The balance between sensitivity/specificity and time efficiency is important in developing an optimal screening battery. While increasing the number of tests in a vision screening battery may improve sensitivity, it involves a time penalty and may also reduce specificity. It has, however, been shown that screening using visual acuity alone can miss up to 40% of children with potentially important vision problems – examples being hyperopia, binocular disorders or ocular disease (Bodack et al., 2010).

**COMPUTERISED VISION SCREENING PROGRAMS**

Computerised screening programs facilitate screening of a broad range of visual parameters in children. An example is the Visual Efficiency Rating (VERA), a computer software program created for school nurses to screen for visual problems that can interfere with reading and school performance – namely, hyperopia, reduced visual acuity, binocular vision dysfunction, accommodation and ocular motility disorders. The VERA screening program takes approximately 12 - 15 minutes for each child (Gallaway & Mitchell, 2010), and was designed to maximise specificity. This was undertaken to alleviate the unwarranted anxiety for parents that is associated with over-referral, which may consequently result in pressure on schools to discontinue vision screening programs.
The sensitivity of the VERA was relatively low at 45% (i.e. 55% of the children failing the screening battery were later determined to not have visual problems), whilst the specificity was 83%. However, the sensitivity and specificity of the VERA improved when combined with a symptom survey (Convergence Insufficiency Symptom Survey), reading level, and a classroom behaviour survey (completed by a teacher), (Gallaway & Mitchell, 2010). The authors concluded that the VERA is more accurate as a screening tool when targeting underachieving children – as determined by the classroom behaviour survey and a test of the child’s reading level (Gallaway & Mitchell, 2010).

Another computer-based vision screening program was developed in the late 1990s (Thomson & Evans, 1999). This involves entry of information regarding the child’s symptoms, history and family history prior to testing, and measurement of distance visual acuity, distance visual acuity through +2.50D lenses, stereoacuity and colour vision. Comparison of the results of this computer-based vision screening program with outcomes from a full eye examination demonstrated high levels of sensitivity and specificity (93.8% and 96.1%, respectively).

PRESCHOOL SCREENING PROGRAMS

The effectiveness of the MCT, NYSOA and VERA has been evaluated for school children; however, the value of vision screening batteries in a preschool setting has not been reported. In 1997, the Vision in Preschoolers (VIP) study investigated eleven screening tests including three separate photoscreeners (Power Refractor II, MTI Photoscreener and iScreen Photoscreener), two autorefractors (Retinomax autorefractor and SureSight Vision Screener), two visual acuity tests (HOTV visual acuity, LEA symbols visual acuity), two stereoacuity tests (Random Dot ‘E’ stereoacuity, Stereo Smile II acuity), non-cycloplegic retinoscopy and the cover-uncover test. Only the latter two required trained personnel for administration.

Non-cycloplegic retinoscopy, Retinomax autorefraction, SureSight Vision Screener and the LEA symbols visual acuity test demonstrated the highest sensitivity for detecting children with amblyopia, strabismus, significant refractive error and/or unexplained reduced visual acuity (Kulp & Vision in Preschoolers (VIP) Study Group, 2009). The VIP study used a set 90% specificity for most tests on the basis that this provided a level appropriate for screenings (10% over-referral rate), (Vision in Preschoolers (VIP) Study Group, 2004). Both autorefractors were in the top three
tests with regards to sensitivity (both at 63%) of all the VIP study’s tests. The autorefractors had the advantage of a short testing time, although are significantly more expensive than the Lea Symbols test, which showed equivalent sensitivity (Kulp & Vision in Preschoolers (VIP) Study Group, 2009). Non-cycloplegic autorefraction also has a tendency to over-minus when compared with non-cycloplegic retinoscopy, so there are disincentives to balance the positives in terms of time benefits (Funarunart et al., 2009; Jorge, Queiros, Almeida, & Parafita, 2005). All three photoscreeners performed poorly in comparison with other tests (Kulp & Vision in Preschoolers (VIP) Study Group, 2009).

The sensitivity and specificity of different vision screening protocols for detecting a range of visual conditions in paediatric populations are presented in Table 2, although it is important to understand that they cannot be compared directly as they were performed on different samples.

VISION SCREENING PROGRAMS CURRENTLY IN USE IN AUSTRALIA

Many different paediatric vision screening programs are currently operational in Australia although there is little coordination between states and territories, and a lack of consensus on how and when children should be screened (Morcos & Wright, 2009). Each Australian state and territory has separate Health Department guidelines (Table 4). Amblyopia and strabismus are the focus of most protocols although risk factors for their development such as anisometropia and uncorrected hyperopia are largely overlooked. Many other relatively common visual conditions such as non-strabismic binocular vision disorders, refractive errors not affecting visual acuity, and ocular health problems are also absent from many of the state-based protocols.

The Healthy Kids Check (HKC) is a federal government sponsored health screening program administered within general medical practices. The HKC targets 4-year old children (Australian Government Department of Health and Ageing, 2012b). The vision component nominally includes a general inspection of the external eyes, measurement of visual acuity (if age appropriate), and a brief history provided by a parent. It allows for referral to an optometrist in the event of concerns by the medical practitioner or nurse who administers the screening (Australian Government Department of Health and Ageing, 2012a). Concerns regarding a lack of clear protocols for the assessors have been raised (Morcos & Wright, 2009). In addition, there is a low rate of provision of the HKC and no data appears to be shared between
or within jurisdictions. Thus, other providers of vision screening programs are not aware of which children have been previously screened as part of the HKC (Morcos & Wright, 2009).

Some private organisations also provide vision screening services to children. The Royal Flying Doctor Service assists with screening of rural Australian communities by nurses, and the Royal Institute for Deaf and Blind children screens over 1200 Aboriginal children per year (Royal Flying Doctor Service, 2010; Royal Institute for Deaf and Blind Children, 2010). Vision screenings are conducted at some primary and secondary schools by local optometrists in an ad hoc manner that is likely driven by the individual optometrist’s interest in paediatric vision and by their available time. As such, screening programs provided by optometrists in private practice result in an important but unmeasured and geographically inconsistent service provision in the community. This conclusion is supported by one of the findings of the NVCSP who identified very few studies that included optometrists in screening processes, despite the significant role they are assumed to play in this regard. As a result of the inconsistent distribution of screening resources in Australia, a co-ordinated, co-management system has been suggested – this strategy proposes that child and family health nurses, optometrists, orthoptists and GPs all play a role as primary screeners (Morcos & Wright, 2009). Importantly, despite this recommendation by the NVCSP, little evidence has emerged to show that this is being implemented.

VISION SCREENING PROGRAMS IN OTHER COUNTRIES

The debate regarding what is the most appropriate protocol for children’s vision screenings is not unique to Australia. In the USA, paediatric vision screening is more common and is incorporated in routine child health assessments and school health programs (Marshall et al., 2010). Nonetheless, there is little agreement about when children should be screened, which conditions should be targeted, protocols that should be used and which screening personnel are best equipped to provide services – issues that are also relevant to Australia. For example, in Indiana all children are required to be screened with the MCT at enrolment to kindergarten or Year 1, and receive additional visual acuity screenings in Years 3 and 8 (Marshall et al., 2010). In Illinois, school vision screening programs are mandated – with the
Department of Public Health providing training and certification in vision screening to school nurses to facilitate compliance (Kimel, 2006).

The Kentucky General Assembly in 2000 passed the first law in the US requiring children in the state of Kentucky aged 3 – 6 years to have a vision examination by an optometrist or an ophthalmologist before the child’s first year at a public school (Zaba, Johnson, & Reynolds, 2003; Zaba et al., 2007). In response to this mandate, the effectiveness of vision screenings conducted during school entrance physical examinations and comprehensive vision examinations performed in Kentucky were compared and indicated that comprehensive eye examinations detected problems not previously found by vision screenings (Zaba et al., 2007). Three hundred children were diagnosed with eye problems, sixty six of which had undergone a previous vision screening. Despite these initiatives, results from the 2002 US National Health Interview Survey revealed that only 36.3% of children aged 5 years or younger had undergone a vision exam of any form (Marshall et al., 2010).

In the United Kingdom (UK), the 1997 National Health Service (NHS) review suggested that preschool vision screenings may not be as beneficial as previously thought, arguing somewhat controversially that the conditions being targeted (amblyopia and refractive error) were “minor” problems, and that there was minimal evidence to demonstrate that treatment was beneficial (Logan & Gilmartin, 2004; Moseley, 1998).

Subsequent to the NHS review, a 2004 UK review by Logan and colleagues examined the evidence-base for the content, provision and efficacy of children’s vision screenings that specifically targeted refractive error, amblyopia, binocular vision and colour vision (Logan & Gilmartin, 2004). In addition, the authors commented on the potential consequences of the curtailment of these screenings following publication of the 1997 review. As a result, they recommended children receive a vision screening between the age of 5 – 6 years (for detection of significant refractive error, colour vision and previously undetected amblyopia), as well as at the age of 11 years to assess for myopia development (Logan & Gilmartin, 2004).

Despite major studies such as the Orinda, Portsea and VIP having broadened the scope of vision screening test content, vision screenings occur in many countries but distance visual acuity alone still forms the basis of these protocols, and other visual parameters are largely ignored. There remains a consequent risk of non-visual acuity...
related conditions remaining undetected. A summary of a number of screening programs conducted in other countries is provided in Table 3.

The current review has demonstrated that there is no universally agreed policy or strategy for vision screening in children – either in Australia or internationally. This is likely a consequence of the paucity of evidence supporting the benefits of screening as well as inconsistent levels of support from relevant authorities and poorly co-ordinated and irregularly distributed service provision involving multiple health professions. Programs that are offered are not well-documented and data are rarely shared. Australian children stand to benefit from improved cohesion and communication between jurisdictions and health professionals to enable an equitable provision of validated vision screening services. Importantly, this provides the best chance of early detection and intervention for a range of paediatric visual problems.
Colour vision deficiency (CVD) – tested with Ishihara

<table>
<thead>
<tr>
<th>Test outcome positive (fails Ishihara)</th>
<th>Test outcome negative (passes Ishihara)</th>
<th>PPV = True positive/test outcome positive</th>
</tr>
</thead>
<tbody>
<tr>
<td>True positive</td>
<td>False negative</td>
<td>= 7/17 = 0.41</td>
</tr>
<tr>
<td>( n = 7 )</td>
<td>( n = 3 )</td>
<td></td>
</tr>
<tr>
<td>False positive (Type I error)</td>
<td>True negative</td>
<td>NPV = True negative/test outcome negative</td>
</tr>
<tr>
<td>( n = 10 )</td>
<td>( n = 100 )</td>
<td>= 100/103 = 0.97</td>
</tr>
</tbody>
</table>

Sensitivity = True positive/condition positive = 7/10 = 0.7

Specificity = True negative/condition negative = 100/110 = 0.9

Figure 1. Calculation of sensitivity, specificity and predictive values, using Ishihara colour vision test results as an example.
Table 1

*Tests included in the MCT*

<table>
<thead>
<tr>
<th>Test Description</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual acuity – measured for each eye</td>
<td>Charts (letters and illiterate E) projected at 20 feet (6 metres)</td>
</tr>
<tr>
<td>Cover test - distance and near</td>
<td>Cover-uncover and alternate-cover tests. A loose prism of 5Δ used for accurate determination of coordination at the cut-off point for distance and 6Δ and 10Δ loose prisms used for near.</td>
</tr>
<tr>
<td>Retinoscopy (skiametry)</td>
<td>Retinoscopy performed with a lens bar containing lenses of -0.75D, +0.75D, +1.50D and +2.25D whilst the child viewed a cartoon film projected on a screen at 20 feet (6 metres) through +1.50D lenses in a trial frame.</td>
</tr>
<tr>
<td>Inspection for organic problems</td>
<td>A hand magnifier and ophthalmoscope used to check for external and internal ocular problems</td>
</tr>
</tbody>
</table>
Table 2

*Sensitivity and specificity of different screening protocols (Kulp & Vision in Preschoolers (VIP) Study Group, 2009; Marshall et al., 2010; Vision in Preschoolers (VIP) Study Group, 2004)*

<table>
<thead>
<tr>
<th>Screening protocol/test</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orinda MCT</td>
<td>96%</td>
<td>98%</td>
</tr>
<tr>
<td>NYSOA screening battery</td>
<td>72%</td>
<td>65%</td>
</tr>
<tr>
<td>VERA</td>
<td>45%</td>
<td>83%</td>
</tr>
<tr>
<td>PowerRefractor II</td>
<td>54%</td>
<td>90%</td>
</tr>
<tr>
<td>MTI Photoscreener</td>
<td>37%</td>
<td>90%</td>
</tr>
<tr>
<td>iScreen Photoscreener</td>
<td>37%</td>
<td>90%</td>
</tr>
<tr>
<td>Retinomax autorefractor</td>
<td>63%</td>
<td>90%</td>
</tr>
<tr>
<td>SureSight Vision Screener</td>
<td>63%</td>
<td>90%</td>
</tr>
<tr>
<td>HOTV visual acuity</td>
<td>54%</td>
<td>89%</td>
</tr>
<tr>
<td>LEA symbols visual acuity</td>
<td>61%</td>
<td>90%</td>
</tr>
<tr>
<td>Random Dot ‘E’ stereoacuity</td>
<td>42%</td>
<td>90%</td>
</tr>
<tr>
<td>StereoSmile II acuity</td>
<td>44%</td>
<td>90%</td>
</tr>
<tr>
<td>Non cycloplegic retinoscopy</td>
<td>64%</td>
<td>90%</td>
</tr>
<tr>
<td>Cover-uncover test</td>
<td>27%</td>
<td>98%</td>
</tr>
<tr>
<td>Portsea MCT</td>
<td>Not reported</td>
<td>Not reported</td>
</tr>
</tbody>
</table>
Table 3

*Examples of vision screening programs conducted in a selection of other countries*

<table>
<thead>
<tr>
<th>Country</th>
<th>Screening program</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweden (Hard, 2007; Kvarnstrom et al., 2001)</td>
<td>By the age of 4, children have received six screenings, followed by two additional screenings during primary school</td>
<td>99% of 4-year old Swedish children have participated in a vision screening Reduction in the prevalence of amblyopia since the increased number of screenings; 0.2% in 1992 compared with 2.0% in 1970</td>
</tr>
<tr>
<td>New Zealand (Anstice, Spink, &amp; Abdul-Rahman, 2012)</td>
<td>Vision Hearing Screening program targets all children between the ages of 4 – 5, as well as at age 11</td>
<td>Vision screening component comprises of a monocular visual acuity test using a single optotype, uncrowded Sheridan-Gardiner letter-matching test; referral for a visual acuity &lt;6/9 Recent study showed that visual acuity measurement alone in this group resulted in a high number of false positives</td>
</tr>
<tr>
<td>East Timor (Ramke, du Toit, Roberts, Pereira, &amp; Hobday, 2011)</td>
<td>Vision and eye health survey conducted to determine whether vision screenings should be included in the Ministry of Health’s ‘Healthy Schools Project’</td>
<td>Only 7 of 1375 students aged 6 – 16 years failed the visual acuity requirement of 6/12 or better in either eye Concluded that due to low prevalence of visual impairment and uncorrected refractive error, and that up to 30% of school-aged children were not enrolled in school, the value of the screening program was questionable</td>
</tr>
</tbody>
</table>
Table 4

*Children’s vision screening guidelines (Australian states and territories)* *(Eye Health Working Group of the Australian Population Health Development Principal Committee, 2008; Morcos & Wright, 2009)*

See Appendix B
APPENDIX B: CHILDREN’S VISION SCREENING GUIDELINES
(AUSTRALIAN STATES AND TERRITORIES)
<table>
<thead>
<tr>
<th>State</th>
<th>Age screened</th>
<th>Screening tests</th>
<th>Screening personnel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Queensland</td>
<td>Neonatal</td>
<td>Eye check, red reflex</td>
<td>Medical practitioner</td>
</tr>
<tr>
<td></td>
<td>0-4 wks; 8 wks; 6 mths; 12 mths; 18 mths</td>
<td>Visual behavior, Hirschberg test (6 and 18 months)</td>
<td>‘Well-child’ visit: child health nurse</td>
</tr>
<tr>
<td></td>
<td>2.5 – 3.5 yrs</td>
<td>Hirschberg test, vision, near cover test</td>
<td>School entry screening: child health nurse</td>
</tr>
<tr>
<td></td>
<td>4 – 5 yrs</td>
<td>Hirschberg test, distance and near cover test, vision: LEA/HOTV/STYCAR</td>
<td>Referred by parent: child health nurse</td>
</tr>
<tr>
<td></td>
<td>6 – 12 yrs</td>
<td>Vision: Snellen chart</td>
<td></td>
</tr>
<tr>
<td>NSW</td>
<td>Neonatal</td>
<td>Eye check, parental questionnaire</td>
<td>Medical practitioner</td>
</tr>
<tr>
<td></td>
<td>1-4 wks; 6-8 wks; 6 mths; 12 mths; 18 mths; 2 yrs; 3 yrs</td>
<td>Observation, fixation, corneal light reflex, CLR (Hirschberg test), response to occlusion, ocular movements, parental questionnaire</td>
<td>Early health check: child and family health nurse, GP, paediatrician</td>
</tr>
<tr>
<td></td>
<td>4 yrs (StEPS – statewide eyesight preschooler program)</td>
<td>Monocular visual acuity/visual inspection/questionnaire</td>
<td>‘Technical assistant’ (trained screeners, some lay-screeners)</td>
</tr>
<tr>
<td>Victoria</td>
<td>Neonatal; 2 wks</td>
<td>Eye examination</td>
<td>MCHN (maternal and child health nurse), GP, paediatrician</td>
</tr>
<tr>
<td></td>
<td>4 wks</td>
<td>Observation, fixation and following</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8 wks; 4 mths; 6-8 mths</td>
<td>Fixation and following</td>
<td></td>
</tr>
<tr>
<td></td>
<td>12 mths</td>
<td>Squint, head tilt, fixation and following</td>
<td></td>
</tr>
<tr>
<td></td>
<td>18-21 mths</td>
<td>Fixation and following</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 yrs</td>
<td>Squint, fixation and following</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.5 yrs</td>
<td>Squint, vision (MIST)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4-5 yrs</td>
<td>Vision (MIST)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>School age</td>
<td>Visual acuity (LEA), questionnaire</td>
<td>School nurse</td>
</tr>
<tr>
<td>South Australia</td>
<td>1-4 wks</td>
<td>Appearance, fixation, red reflex</td>
<td>Paediatrician or GP and visiting community nurse</td>
</tr>
<tr>
<td></td>
<td>6-8 wks</td>
<td>Appearance, fixation and following</td>
<td>Health centre community nurse with orthoptist</td>
</tr>
<tr>
<td></td>
<td>6-9 mths; 18 mths; 2-3.5 yrs</td>
<td>Appearance, fixation and following, CLR (6-9 months)</td>
<td>Kindergarten or health centre community nurse</td>
</tr>
<tr>
<td></td>
<td>4-5 yrs</td>
<td>Distance visual acuity</td>
<td></td>
</tr>
<tr>
<td>State</td>
<td>Age</td>
<td>Examination Details</td>
<td>Health Professionals</td>
</tr>
<tr>
<td>-------</td>
<td>-------</td>
<td>-------------------------------------------------------------------------------------</td>
<td>---------------------------------------------</td>
</tr>
<tr>
<td>Tasmania</td>
<td>1-2 wks</td>
<td>Eye check, questionnaire</td>
<td>Family and Child Health Nurse, GP, pediatrician</td>
</tr>
<tr>
<td></td>
<td>6-8 wks</td>
<td>CLR, fixation and following</td>
<td>Family and Child Health Nurse</td>
</tr>
<tr>
<td></td>
<td>6 mths; 18 mths</td>
<td>CLR, red reflex, cover test, questionnaire</td>
<td>Family and Child Health nurse (CLR, cover) and GP (CLR, red reflex, cover)</td>
</tr>
<tr>
<td></td>
<td>3.5 yrs</td>
<td>Visual acuity, CLR, eye movements, red reflex, ophthalmoscopy, questionnaire, cover test</td>
<td>Family and Child Health nurse (CLR, cover, visual acuity) and GP (ophthalmoscopy, eye movements, CLR, red reflex, visual acuity)</td>
</tr>
<tr>
<td></td>
<td>5-12 yrs</td>
<td>Distance vision (Prep and Year 6)</td>
<td>Family and Child Health nurse</td>
</tr>
<tr>
<td>ACT</td>
<td>1-4 wks</td>
<td>Visual observation</td>
<td>Child health nurse</td>
</tr>
<tr>
<td></td>
<td>6-8 wks; 6 mths; 12 mths 18 mths</td>
<td>Visual observation, cover-uncover test</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 yrs</td>
<td>Visual acuity (Striker cards)</td>
<td>School nurse</td>
</tr>
<tr>
<td></td>
<td>5-6 yrs</td>
<td>Visual acuity (Snellen, Sheridan-Gardiner)</td>
<td></td>
</tr>
<tr>
<td>WA</td>
<td>Neonatal</td>
<td>Red reflex</td>
<td>Community Health Nurse</td>
</tr>
<tr>
<td></td>
<td>6-8 wks; 3-4 mths</td>
<td>Red reflex, questionnaire</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8 mths</td>
<td>CLR</td>
<td></td>
</tr>
<tr>
<td></td>
<td>18 mths; 3 yrs</td>
<td>Questionnaire</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.5-5 yrs</td>
<td>Cover test, CLR, visual acuity (LEA)</td>
<td></td>
</tr>
<tr>
<td>NT</td>
<td>Neonatal</td>
<td>Red reflex</td>
<td>Nurse, Allied Health Worker</td>
</tr>
<tr>
<td></td>
<td>8 wks</td>
<td>Fixation and following</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6 mths</td>
<td>Visual observation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>18 mths</td>
<td>Vision (eye contact)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4-5 yrs</td>
<td>Visual acuity (LEA chart)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5-15 yrs</td>
<td>Yearly trachoma screening (remote areas)</td>
<td></td>
</tr>
</tbody>
</table>
## APPENDIX C: POWER ANALYSIS

<table>
<thead>
<tr>
<th>Effect size</th>
<th>Standard deviation</th>
<th>Sample size required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effect size = ((\text{mean score}) - (\text{estimated mean score of children with condition/or experiencing difficulty in this area})).</td>
<td>Standard deviation required = ((21 \times s^2)) /(\text{effect size})^2</td>
<td></td>
</tr>
<tr>
<td><strong>Hyperopia</strong></td>
<td>Mean refractive error at 12 years of age, +0.86DS (Rose, Morgan, Smith, et al., 2008) – minimum level of hyperopia that should be corrected regardless of symptoms, +1.50DS (Rosner &amp; Rosner, 1997)</td>
<td>0.76 (Rose, Morgan, Smith, et al., 2008)</td>
</tr>
<tr>
<td><strong>Stereoacuity</strong></td>
<td>Mean stereoacuity, 25 seconds of arc (Jimenez et al., 2004) – estimated mean score of children with reduced stereopsis, 40 seconds of arc</td>
<td>10 (Jimenez et al., 2004)</td>
</tr>
<tr>
<td><strong>Accommodative facility</strong></td>
<td>Mean binocular accommodative facility, 8cpm (Zellers et al., 1984) – estimated mean of binocular accommodative facility of children with reduced facility, 6cpm</td>
<td>5 (Zellers et al., 1984)</td>
</tr>
<tr>
<td><strong>DEM</strong></td>
<td>Mean ratio score of horizontal time to vertical time, 1.19 (Garzia et al., 1990) – estimated mean ratio score of children with ocular motor dysfunction, 1.4</td>
<td>0.17 (Rateau, Laumonier, &amp; Hyndman, 2003)</td>
</tr>
</tbody>
</table>
# APPENDIX D: EQUIPMENT LIST

<table>
<thead>
<tr>
<th>Station 1</th>
<th>Station 2</th>
<th>Station 3</th>
<th>Stations 4 and 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Randot stereotest</td>
<td>Beery’s Test of VMI – photocopied recording sheets</td>
<td>NEALE reader</td>
<td>Occluder</td>
</tr>
<tr>
<td>Polarised glasses</td>
<td>Pens</td>
<td>Photocopied NEALE recording sheets</td>
<td>Distance letter chart</td>
</tr>
<tr>
<td>Tape measure</td>
<td>DEM test</td>
<td>Vision screening protocol</td>
<td>Tape measure and ruler</td>
</tr>
<tr>
<td>Ishihara test</td>
<td>Timer</td>
<td></td>
<td>Tape/adhesive</td>
</tr>
<tr>
<td>Bailey Lovie 3m chart</td>
<td>Protocol</td>
<td></td>
<td>6/12 near target (N6) at 40cm</td>
</tr>
<tr>
<td>LEA symbols 3m chart and matching card</td>
<td></td>
<td></td>
<td>Horizontal prism bar</td>
</tr>
<tr>
<td>Tape/adhesive</td>
<td></td>
<td></td>
<td>6/9 near target (N5) at 40cm</td>
</tr>
<tr>
<td>Eye patch</td>
<td></td>
<td></td>
<td>+/- 2D flippers</td>
</tr>
<tr>
<td>Vertometer</td>
<td></td>
<td></td>
<td>Timer</td>
</tr>
<tr>
<td>Near Howell-Dwyer phoria card</td>
<td></td>
<td></td>
<td>Retinoscope</td>
</tr>
<tr>
<td>Distance Howell-Dwyer phoria card</td>
<td></td>
<td></td>
<td>Ret rack</td>
</tr>
<tr>
<td>2x 6Δ prisms (1 x loose prism, and 1 x prism with stick)</td>
<td></td>
<td></td>
<td>String</td>
</tr>
<tr>
<td>+/- 2D flippers</td>
<td></td>
<td></td>
<td>Direct ophthalmoscope and charger</td>
</tr>
<tr>
<td>Protocol</td>
<td></td>
<td></td>
<td>Tissues</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cyclopentolate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Atomiser</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sunglasses</td>
</tr>
</tbody>
</table>
APPENDIX E: QUESTIONNAIRE

Thank you for consenting to allow your child to participate in this research project. Please take a few minutes to complete the following questions relating to your child’s vision and visual tasks.

Child’s year level: __________  Child’s gender: Male / Female

1. Does your child identify as Aboriginal?  Y / N
   Does your child identify as Torres Strait Islander?  Y / N
   Does your child identify as both Aboriginal and Torres Strait Islander?  Y / N

2. Has your child ever attended a vision screening or received an eye examination?  
   Y / N
   If yes, please advise your child’s age when examined and where  
   ___________________ (optometrist/school/medical centre)?

3. Has your child ever had glasses?  Y / N
   If yes, please advise your child’s age when examined ________________,
   and what for  ____________________
   (reading/distance/all the time)?

4. Has your child ever had any medical/surgical treatment to their eyes?  Y / N
   If yes, please provide details
   ________________________________

5. Is there a family history of eye problems, e.g. turned or lazy eyes?  Y / N
   If yes, please provide details
   ________________________________
6. **Does your child ever experience the following?** Please circle.

- One eye turns in or out while the other points straight ahead?  Y / N
- Tilting head noticeably?  Y / N
- Poor hand-eye coordination?  Y / N
- Covering or closing one eye?  Y / N
- Difficulty learning to read?  Y / N
- Hold a book very close to read?  Y / N
- Leaving out or confusing words when reading?  Y / N
- Squinting or sitting very close when watching television?  Y / N
- Difficulty recognising familiar people in the distance?  Y / N
- Complains of headaches?  Y / N
- Complains of blurred or double vision?  Y / N

7. **On average, how many hours does your child spend reading each day outside of school hours (for leisure or homework)?** Please circle.

   Less than 1 hour / 1 – 2 hours / 3 or more hours

8. **On average, how many hours does your child spend on the computer or video games outside of school hours?** Please circle.

   Less than 1 hour / 1 – 2 hours / 3 or more hours

9. **Does your child have any general health problems?**  Y / N

   If yes, please provide details _________________________________

   **a.** Has your child experienced hearing/ear problems in the past?  Y / N

   **b.** Did your child have a low birth weight?  Y / N

   **c.** Does your child have any known allergies to pupil-dilating eye drops?  Y / N

10. **Are there any other concerns you have with your child’s vision?**  Y / N

    If yes, please provide details _________________________________
APPENDIX F: TESTING PROTOCOL

1. Randot stereotest – Student 1
   - Randot stereotest is held at 40cm from the child in an upright position.
   - Child wears the polarising filters (over prescription glasses).
   - Direct the child to the graded circles test – ask which circle appears to float or appear different from the others, left, middle or right? Assist the child by running your finger across all three circles and allowing them to point to the answer. If one is missed, go back to preceding circles to check if child can see this, or has guessed correctly.
   - Direct the child to the Randot test – ask which area does not have a shape/letter in it (for both top and bottom Randot tests). Allow the child to study it for a while, and to also point with their fingers if required.
   - **Scoring.** Record the level of stereopsis for the last group of circles selected correctly (seconds of arc). Record the level of stereopsis (500sec, 250sec or none) achieved with the Randot test.
   - **Instruments required.** Randot stereotest, polarised glasses, tape measure.

   ![Randot scoring](Plate 17)

<table>
<thead>
<tr>
<th>SCORING KEY</th>
<th>Seconds of arc at 16 in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>L 400</td>
</tr>
<tr>
<td>2</td>
<td>R 200</td>
</tr>
<tr>
<td>3</td>
<td>L 140</td>
</tr>
<tr>
<td>4</td>
<td>M 100</td>
</tr>
<tr>
<td>5</td>
<td>R 70</td>
</tr>
<tr>
<td>6</td>
<td>M 50</td>
</tr>
<tr>
<td>7</td>
<td>L 40</td>
</tr>
<tr>
<td>8</td>
<td>R 30</td>
</tr>
<tr>
<td>9</td>
<td>M 25</td>
</tr>
<tr>
<td>10</td>
<td>R 20</td>
</tr>
</tbody>
</table>

2. Ishihara colour vision test
   - The Ishihara test is held at arm’s length (approximately 66cm) from the child.
   - The child wears their habitual correction for near.
   - The examiner instructs the child to ‘Tell me the numbers that you can see as I turn the pages. Sometimes you will not see a number and then I will turn to the next page.’
   - The examiner turns the pages in the Ishihara allowing approximately 4 seconds for each page up until the 17th plate, i.e. 42.
   - **Scoring.** Record the number of errors.
   - **Instruments required.** Ishihara colour vision test, tape measure.
3. Monocular distance visual acuity

- The measurement procedure, termination rule and scoring method used by the VIP will be used in this study.
- Children in Year 1 will be tested with the LEA symbols logMAR chart.
- Children in Years 2, 6 and 7 will be tested with the Bailey-Lovie letter chart.
- With their habitual correction, the child will be asked to read the top line of letters on the chart. If all are read correctly, they are then asked to read two letters/symbols out on each subsequent line until an incorrect response is given.
- The child is then directed to the line above that where the incorrect response was given, and asked to read out the remaining 3 letters/symbols. If less than 3 of the five are identified correctly, the child is directed to the line above until 3 are read correctly.
- Once three of the five are identified correctly, the child then reads all letters/symbols on each line down the chart, until no letters in a given line are identified correctly.
- The child’s visual acuity is scored as a logMAR value. The logMAR for the last line where 3 letters/symbols were identified correctly is the score, plus a value -0.02 log units for each correctly identified optotype beyond this line, e.g. 6/9 (3 letters correct), ++++++
- Record visual acuity for right and left eyes.
- If the child’s visual acuity is recorded with spectacles, record right and left visual acuity unaided as well.
- **Instruments required.** Bailey-Lovie 3m letter chart, LEA symbols 3m letter chart, tape measure, tape, eye patch, LEA matching card, vertometer.

4. Phorias

- The distance Howell-Dwyer phoria card is placed at a distance of 3m from the child. The child is wearing their habitual distance correction.
- The child is asked whether they can see the blue and the yellow sides of the chart and the arrow. A loose 6Δ prism is placed in a base down direction in front of the child’s right eye. The child is asked if they can now see two arrows – they are directed to the top arrow, and asked if it is pointing down to the blue side or the yellow side, and what number is it pointing closest to.
- The same procedure is performed at near, with the near Howell-Dwyer phoria card held at a distance of 33cm from the child. The child wears their habitual near correction.
- **Instruments required.** Distance and near Howell-Dwyer phoria card, 6Δ loose prism lens.

5. AC:A ratio

- The AC:A ratio will be measured with by the gradient method and with ±2.00D flippers.
- After measuring the near phoria with the Howell-Dwyer phoria card, the examiner will place the +2.00D lenses (flipper) in front of the child in addition to the 6Δ base down right loose prism and record the new heterophoria value; this is then repeated with -2.00D lenses.

6. Pupil assessment/anterior eye examination/direct ophthalmoscopy

- Pupil assessment, direct ophthalmoscopy and gross external examination will be conducted with the direct ophthalmoscope.
7. Beery’s Test of Visual Motor Integration – Student 2

- The booklet is placed faced down in front of the child and squared to the desk. The test booklet and child’s body should remain centred and squared to the desk throughout testing.
- When the child draws, ask the child to hold the booklet. If the child does not eventually hold it, the examiner should hold it and keep it straight and centred to the child’s body.
- The examiner should point to task 7 (vertical line) and then to the blank space below it and say – make one like that, make yours right here.
- The examiner can encourage the child but should not trace the form with pencil/finger or allow the child to trace the form. The examiner should also avoid calling the form by its name or by a descriptive term.
- As many times as necessary, the examiner can prompt by pointing to an item and say – make one like this.
- The examiner should allow only one try per task – allow only one single line strokes, not thickened or hollow lines. Once the child is responding well, the examiner should say – ‘good, go ahead and do the rest of them, turn to the next page when you finish this one; do your best on both the easy and the hard ones, do not skip any.’
- The test is ended once all boxes are completed.
- Instruments required. VMI recording sheets, pens.

8. Developmental Eye Movement Test

- This test consists of two vertical subtests and one horizontal subtest.
- The first vertical subtest is placed in front of the child seated at the desk with their habitual reading correction. The examiner asks to the child to carefully read the numbers aloud down the two columns as quickly as possible. The child should avoid head movements and finger pointing.
- The examiner records the time to complete the task to the nearest 10th of a second, and records the number of errors.
- This is repeated for the second vertical subtest.
- The examiner then places the horizontal subtest in front of the child and asks the child to carefully read aloud the numbers across the rows, as in reading, as quickly as possible.
- Scoring. Time to complete each subtest is recorded as well as number of errors for each subtest.
- Instruments required. DEM subtests, timer.
9. NEALE Analysis of Reading Ability Test – Student 3

- This test is made up of a reader, and an individual record – scoring sheet.
- The examiner should first establish a basal level of the child’s reading ability – this is achieved with the word lists on page 81 of the reader.
- Before opening the reader, say to the child – ‘Here is a short story book. I should like you to read some of the stories, and tell me which story you like best.’
- Open to page 81, begin at level 1 and say – ‘I want to see how many of these words you can read. Some of them are fairly easy but others are a little harder. Begin here (point to first word starting point) and then read the words down the page like this’ (run finger down the lines of words to be read, progressing systematically from one level to the next).
- Record basal level on scoring sheet – on page 7 of scoring sheet, circle incorrect words and cross words not attempted. The test is stopped when the child makes 2 errors in a level. The basal level is the level prior to the level where 2 errors were made.
- The examiner then turns to the appropriate passage for beginning the test – i.e. basal level, however, for basal levels > 3, still begins the child on reading passage level 3.
- Say – ‘Look at this picture and then read the story to me. If you come to a hard word, try it aloud by yourself before I help you. I am going to record the time it takes you to read, but it is important to read carefully and to remember what you read. At the end, I shall ask you some questions, so try to remember the story as you read it.’
- Start the timer as the child reads the first word, and stop when the last word is read. Mark any errors on the appropriate passage on the inside of the individual record. Begin asking the comprehension questions immediately after the individual has completed reading the passage. It is preferable to leave the reader open at the narrative the child has just read, but if it is obvious that the student is returning to search the text for responses, provide a reminder to answer from memory. If, after this reminder, the individual continues such a strategy, give credit for correct answers but note this strategy. Where the individual does not know the answer or replies incorrectly, the examiner should move to the next question without supplying the correct answer.
- At the end of the test, if the child is struggling or has made too many errors the examiner should say ‘That’s fine, I think we shall stop here. What was that story about?’ or ‘How do you think it was going to end?’ or ‘Well done – lets finish this story off together.’
- The testing is stopped when the child reaches the passage in which 16 or more errors have been made for passages 1 – 5, or 20 errors for passage 6. Do not give the comprehension questions for any passage when the permissible number of errors (16 or 20) has been exceeded.
- Stop testing if a child makes between 8 and 10 errors on passage level 1.
- Stop testing in the case where a child has made 12 errors on a completed passage between level 1 and 5 – but still ask the comprehension questions.
- Scoring. Write exactly what the child reads above the relevant passage in Form 1 – (see example below). Classify errors above passage as MIS – mispronunciations, SUB – substitutions, real words used instead of word in passage, REF – refusals, unable to make attempt at the word, ADD – additions, words or parts of words inserted in text, OM – omissions, REV – reversals, ‘no’ for ‘on’. Disregard of punctuation and hesitations are not errors, if individual self corrects, it is not an error. If self-corrects, and is wrong – SUB error. It is more critical to tally errors correctly, than categorising errors correctly.
- Instruments required. NEALE reader, NEALE scoring sheets, timer, NEALE instruction manual (for reference).
10. Cover test – Shelley (supervising optometrist)

- The unilateral cover test will be performed at distance and near to detect any strabismus, and the alternating cover test will be performed at distance and near to detect any vertical phorias.
- At distance, the child will be directed to a letter at 3m which is one line above their best habitual visual acuity. The unilateral cover test is performed by observing any movement of the uncovered eye as the other eye is covered. The direction of any strabismus will be recorded. The alternating cover test is performed by observing the movement of the covered eye on removal of the cover – direction of any vertical heterophorias will be recorded.
- At near, the same tests are performed, however the child is directed to a 6/12 letter target (N6) at 40cm.
- **Instruments required.** Occluder, distance letter chart, 6/12 near target, tape measure.

11. Fusional vergence range

- Positive and negative fusional vergence range will be measured at both distance and near with prism bars.
- Negative fusional vergence is measured first at distance. The child is directed to a fixation one letter above best habitual visual acuity. Low powered BI prism is introduced in front of the child’s habitual correction. Increasing levels of prism are introduced until the child reports diplopia or the examiner observes the eye moving in – losing fixation; lesser amounts of prism power are then re-introduced until the child reports single vision or the examiner observes fusion again. This procedure is repeated 3 times and results recorded. Positive fusional vergence is then measured at distance with the same procedure as above, but using BO prism.
- Negative fusional vergence is then measured at near – the child is directed to a 6/12 letter (N6) at 40 cm, they are wearing their near habitual correction. As above, BI prism of increasing power is introduced until diplopia is reported or the examiner observes a loss of fixation. Following this break point, lesser powered prism is re-introduced until fusion is regained. This is repeated 3 times and recorded. Positive fusional vergence is finally measured at near with the same procedure mentioned above, but using BO prism.
  - **Scoring.** Break and recovery points are recorded for all three measurements for positive and negative fusional vergence at distance and near.
  - **Instruments required.** Horizontal prism bar, distance letter chart, 6/12 near target.

---

Bird (Level 1)

C R (qf) m e (xh) n (fe) i t (xh) s o m e t h i n g (xh) s n (xh) (fe) b a b i e s (xh)

A bird hopped up to my window. I gave her some bread. She made a nest in my garden. Now I look after her little ones.

(26 words)
12. Near point of convergence

- The standardised measurement protocol used by the Convergence Insufficiency and Reading Study Group to measure NPC will be used in this study.
- An accommodative target, single column of 6/9 letters (N5) at 40cm, is brought towards the child until diplopia is reported by the child, or the examiner observes a deviation of the eyes. The break value is measured from the bridge of the nose. The accommodative target is then moved back from the break point, until the child reports single vision, or the examiner observes fusion – this distance is measured as the recovery point. This procedure is repeated a total of 3 times.
- **Instruments required.** Measuring tape, single column of 6/9 letters for near target.

13. Accommodative facility

- Binocular accommodative facility will be measured with ±2.00D flippers with a 6/9 (N5) accommodative target held at a distance of 40cm.
- The child is directed to a line of 6/9 letter targets and asked to read the letters out loud. The child is wearing their near habitual correction. The +2.00D lenses are introduced in front of the child’s eyes and the child is asked to continue reading when the letters become clear again. The -2.00D lens is then flipped in front of the child’s eyes and again the child is asked to continue reading the letters when they become clear again. This is continued for 60 seconds, counting the number of cycles that take place – 1 cycle is when both the +2.00D and -2.00D lenses have been flipped and cleared.
- **Instruments required.** ±2.00D flippers, 6/9 reading target – line of letters or words, timer.

14. Shadow test/pupils/instillation of cyclopentolate

- Shadow test is performed on one eye under dim illumination whilst participant fixates on 6/60 target
  - If nasal illumination is 75% or greater, grading of anterior chamber angle is Grade 3 – 4, and safe to dilate (i.e. shadow is ¼ of nasal iris or less)
- Any known allergies to mydriatic drugs is checked
- 1% cyclopentolate spray to be administered to closed eyelid of one eye
- After 25 minutes, cyclopentolate will be checked: i.e. pupils greater than 6mm and light reflex is absent
- **Instruments required.** Direct ophthalmoscope, cyclo spray, tissues.

15. Retinoscopy

- The examiner will perform streak retinoscopy (Welch Allyn retinoscope) in a dimly lit room. The examiner will be at a distance of 67cm from the child and the child will be asked to look at a 6/60 letter target 3m away.
  - A retinoscopy rack will be used to determine the refractive power required to neutralise the streak movement in both the horizontal and vertical meridians. Retinoscopy will be performed on both eyes.
  - **Instruments required.** Retinoscope, distance letter chart, retinoscopy rack.
16. **Direct ophthamoscopy.**

- Fundus examination will be performed with direct ophthamoscopy after cycloplegia.

**Give child report, after hours contact number and sunglasses.**
APPENDIX G: EXAMPLE TIMELINE FOR A TESTING DAY

<table>
<thead>
<tr>
<th>Time</th>
<th>Station 1</th>
<th>Station 2</th>
<th>Station 3</th>
<th>Station 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.15am</td>
<td>Participant 1</td>
<td>Participant 2</td>
<td>Participant 3</td>
<td>Participant 4</td>
</tr>
<tr>
<td>9.30am</td>
<td>Participant 2</td>
<td>Participant 3</td>
<td>Participant 4</td>
<td>Participant 1</td>
</tr>
<tr>
<td>9.45am</td>
<td>Participant 3</td>
<td>Participant 4</td>
<td>Participant 1</td>
<td>Participant 2</td>
</tr>
<tr>
<td>10.00am</td>
<td>Participant 4</td>
<td>Participant 1</td>
<td>Participant 2</td>
<td>Participant 3</td>
</tr>
<tr>
<td>10.15am</td>
<td>Participant 5</td>
<td>Participant 6</td>
<td>Participant 7</td>
<td>Participant 8</td>
</tr>
<tr>
<td>10.30am</td>
<td>Participant 6</td>
<td>Participant 7</td>
<td>Participant 8</td>
<td>Participant 5</td>
</tr>
<tr>
<td>10.45am</td>
<td>Participant 7</td>
<td>Participant 8</td>
<td>Participant 5</td>
<td>Participant 6</td>
</tr>
</tbody>
</table>

**RECESS**

<table>
<thead>
<tr>
<th>Time</th>
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<th>Station 2</th>
<th>Station 3</th>
<th>Station 4</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Participant 8</td>
<td>Participant 5</td>
<td>Participant 6</td>
<td>Participant 7</td>
</tr>
<tr>
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<td>Participant 9</td>
<td>Participant 10</td>
<td>Participant 11</td>
<td>Participant 12</td>
</tr>
<tr>
<td>12.20pm</td>
<td>Participant 10</td>
<td>Participant 11</td>
<td>Participant 12</td>
<td>Participant 9</td>
</tr>
<tr>
<td>12.35pm</td>
<td>Participant 11</td>
<td>Participant 12</td>
<td>Participant 9</td>
<td>Participant 10</td>
</tr>
<tr>
<td>12.50pm</td>
<td>Participant 12</td>
<td>Participant 9</td>
<td>Participant 10</td>
<td>Participant 11</td>
</tr>
</tbody>
</table>

**LUNCH**

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<th>Station 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.50pm</td>
<td>All participants – Station 5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.45pm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

APPENDIX H: RESULTS SHEET
# Results sheet

<table>
<thead>
<tr>
<th>Year level:</th>
<th>Age:</th>
<th>Male/Female</th>
<th>ATSI/non-ATSI</th>
</tr>
</thead>
</table>

## History taking:

- Questionnaire attached: Y / N

## Stereoacuity:

- **Randot stereopsis**: none/250secs of arc/500secs of arc
- **Graded circles**: ____________ secs of arc

## Colour vision – Ishihara:

- **Number of errors**: ____________

## Visual acuity:

- **Distance visual acuity**:
  - R: ____________
  - L: ____________
  - Unaided

- **Spectacle power**:
  - R: +2.00
  - L: 0

## Phorias (H-D):

- **D**: ____________
- **N**: ____________

## AC/A:

- +2.00
- 0
- -2.00

## Visual motor integration:

*Attach Beery VMI recording and score sheet.*

## Developmental Eye Movement test:
Vertical subtest 1: Time _______ secs  Vertical subtest 2: Time _______ secs  
Errors _______  Errors _______

Horizontal sub-test: Time _______
Errors _______

**Neale Analysis of Reading Ability**

*Attach NEALE individual record sheet.*

---

**Binocular vision assessment**

Cover test  D  N

Fusional vergence range (break/recovery)

<table>
<thead>
<tr>
<th></th>
<th>(BI)</th>
<th>(BO)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>1.</td>
<td>1.</td>
</tr>
<tr>
<td></td>
<td>2.</td>
<td>2.</td>
</tr>
<tr>
<td></td>
<td>3.</td>
<td>3.</td>
</tr>
<tr>
<td>N</td>
<td>1.</td>
<td>1.</td>
</tr>
<tr>
<td></td>
<td>2.</td>
<td>2.</td>
</tr>
<tr>
<td></td>
<td>3.</td>
<td>3.</td>
</tr>
</tbody>
</table>

NPC (break/recovery) 1. _____ cm  
2. _____ cm  
3. _____ cm  

Accommodative facility _____ cycles/minute

---

**Retinoscopy and ocular health:**

Pupil assessment: RAPD Y/N  P E R R L A
Gross external examination:

__________________________________________________________________________

__________________________________________________________________________

Shadow test:  R  (amount of nasal shadow) ______________________

L  (amount of nasal shadow) ______________________

Known allergies to mydriatics:  Y / N        Time spray administered: ____________

Time retinoscopy performed:

Retinoscopy

R        L

Ocular health

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________
APPENDIX I: BOX PLOTS SHOWING RESULTS FOR INDIVIDUAL VISUAL MEASURES, BY INDIGENOUS STATUS

Box plots for the binocular vision measures as a function of Indigenous status including near point of convergence, heterophoria and fusional vergence, as well as visual motor integration and RAN results.

Box plots for NPC break point (centimetres) by Indigenous status

Box plots for near horizontal heterophoria by Indigenous status

*y-axis: negative values represent esophoria, positive values represent exophoria
Positive fusional vergence at near - break

Box plots for positive fusional vergence at near (break)

Positive fusional vergence at near - recovery

Box plots for positive fusional vergence at near (recovery)
Box plots for negative fusional vergence at near (break)

Box plots for negative fusional vergence at near (break)
Box plots for VMI standardised score, by Indigenous status

Box plots for DEM raw vertical scores for Years 1 and 2 children, by Indigenous status
Box plots for DEM raw vertical scores for Years 6 and 7 children, by Indigenous status
APPENDIX J: BOX PLOTS SHOWING RESULTS FOR READING OUTCOMES, BY AGE, INDIGENOUS STATUS AND VMI SCORES

Box plots of reading comprehension percentile scores for Years 1 and 2 children, by VMI ability

Box plots of reading accuracy percentile scores for Years 1 and 2 children, by VMI ability
Box plots of reading comprehension percentile scores for Years 6 and 7 children, by VMI ability

Box plots of reading accuracy percentile scores for Years 6 and 7 children, by VMI ability
APPENDIX K: MAILED SURVEY AND ONLINE SURVEY

Queensland Health Kindergarten and Primary School Vision Screenings Survey

Name of hospital/health service: | Health Service District:
---|---

Are vision screenings conducted on kindergarten – year 1 (4 – 7 year old) children in your region? (This can include vision screenings conducted in combination with other screenings, e.g. hearing).

☐ Yes  ☐ No

If you answered **yes** to the above question, please continue with the questions below.

If you answered **no** to the above question, you have completed the questionnaire. Please return it to QUT in the enclosed envelope, thank you for your time.

1. Where are the vision screenings conducted? E.g. Primary schools, kindergartens, community health centres.

2. What age group/year level(s) do the vision screenings target? E.g. 4 year olds, year prep, year 1, all year levels.

3. Are the vision screenings conducted in isolation, or in combination with other screenings?

☐ Only vision is screened

☐ Vision is screened in combination with other screenings. Please list other screenings (e.g. hearing, height, weight):
4. How often do the vision screenings take place at each school? E.g. At the start of each year, annually, twice a year.

5. What is the estimated coverage of the screenings? E.g. What number of children were screened last year / what percentage of schools/kindergartens are visited annually.

6. What tests are included in the vision screening? E.g. STYCAR visual acuity testing at 6m, cover test.

7. What is the referral criterion for each test?

8. What is the procedure for ensuring follow-up is taken?

9. What is the procedure for children who have difficulty completing the vision screening? E.g. re-screened at a later date, referred for an eye examination.

10. Are the classroom teachers/principals made aware of which children require follow-up?
Which vision screening services exist for Queensland primary school children?

Background information.

1. Are you male or female?
   Please pick one of the answers below.
   Male
   Female

2. How many years has it been since you graduated as an optometrist?
   Please pick one of the answers below.
   5 years or less
   6 - 10 years
   11 - 20 years
   More than 20 years

3. From which university did you graduate?
   Please pick one of the answers below or add your own.
   Queensland University of Technology
   University of New South Wales
   University of Melbourne
   University of Auckland
   Other (please specify)

4. Are you a member of the Australasian College of Behavioural Optometrists (ACBO)?
   Please pick one of the answers below.
   Yes
   No

5. What region/s do you practise in?
   Please check all that apply.
   Brisbane - Metro North
   Brisbane - Metro South
   Gold Coast
   Sunshine Coast - Wide Bay
   Darling Downs - West Moreton
   South West Queensland
   Central West Queensland
   Central Queensland
   Mackay
   Townsville
   Mt Isa
   Cairns and Hinterland
   Cape York
   Torres Strait - Northern Peninsula

Patient base.

6. How many patients do you see in your practice on average each week?
   Please pick one of the answers below.
   35 or less
   36 - 55
   56 - 75
   More than 75

7. How many primary school children (4 - 13 years old) do you see in your practice on average each week?
   Please pick one of the answers below.
   Less than 1
   2 - 5
   6 - 10
   More than 10

8. How many Aboriginal and/or Torres Strait Islander primary school children (4 - 13 years old) do you see in your practice on average each week?
   Please pick one of the answers below.
   Less than 1
   2 - 5
   6 - 10
   More than 10

Vision screening referrals.

9. In the last year, have you seen any primary school children (4 - 13 years old) who were referred for an eye examination from a vision screening?
   Please pick one of the answers below.
   Yes
   No

10. In the past month, approximately how many primary school children (4 - 13 years old) have you seen who presented for an eye examination from a vision screening?
    Please pick one of the answers below.
    5 or less
    6 - 15
    16 - 25
    More than 25

11. What year level were the children who had been referred from a vision screening?
    Please check all that apply.
    Entering Prep in the following year
    Prep
    Year One
    Years 2 - 3
    Years 4 - 5
    Years 6 - 7
    Don't know

12. Who conducted the vision screening? Please select all that apply.
    Please check all that apply and/or add your own variant.
    Optometrist
    GP
    Nurse
    Don't know
    Other (please specify)
13. What findings were recorded on the vision screening referral?  
Please check all that apply and/or add your own variant.  
Monocular distance visual acuity  
Binocular distance visual acuity  
Monocular near acuity  
Binocular near acuity  
Distance cover test  
Near cover test  
Stereopsis  
Colour vision  
Other (please specify)  

14. What were the main reasons for referrals from the vision screenings?  
Please check all that apply and/or add your own variant.  
Monocular distance visual acuity  
Binocular distance visual acuity  
Monocular near visual acuity  
Binocular near visual acuity  
Distance cover test  
Near cover test  
Stereopsis  
Colour vision  
Other (please specify)  

15. Approximately what proportion of children who were referred from a vision screening required the following optometric management?  
Please mark the corresponding circle - only one per line.  

[ ] >75%  
[ ] 50 - 75%  
[ ] 25 - 50%  
[ ] <25%  

Spectacles  
Vision therapy  
Specialist referral  
No management at this stage, review within 2 years  
No management required  

16. Please feel free to provide any further information on vision screening services provided to primary school children in your region.  
Please write your answer in the space below.  

Vision screening participation.  

17. In the last year, have you been involved in any vision screenings on primary school children outside your practice?  
Please pick one of the answers below.  
Yes  
No  

18. Where were the vision screenings conducted?  
Please check all that apply and/or add your own variant.  
School  
Community centre  
Other (please specify)  

19. In the past, in what region/s of Queensland have you participated in vision screenings outside your practice?  
Please check all that apply.  
Brisbane - Metro North  
Brisbane - Metro South  
Gold Coast  
Sunshine Coast - Wide Bay  
Darling Downs - West Moreton  
South West Queensland  
Central West Queensland  
Central Queensland  
Mackay  
Townsville  
Mt Isa  
Cairns and Hinterland  
Cape York  
Torres Strait - Northern Peninsula  

20. How often do you participate in vision screenings outside your practice?  
Please pick one of the answers below.  
5 or more time per year  
3 - 4 times per year  
1 - 2 times per year  
Less than yearly  

21. Approximately how many children are seen at each vision screening?  
Please pick one of the answers below.  
Less than 20  
30 - 50  
50 - 100  
More than 100  

22. Who coordinates the vision screenings?  
Please select more than one answer, if appropriate.  
Please check all that apply and/or add your own variant.  
Yourself  
School  
Queensland Department of Health (Child and Health Nurse)  
Queensland Department of Education  
Other (please specify)  

23. Which of the following tests are included in the vision screenings? Please select all that apply.  
Please check all that apply and/or add your own variant.  
Monocular distance visual acuity  
Binocular distance visual acuity  
Monocular near visual acuity  
Binocular near visual acuity  
Distance cover test  
Near cover test  
Stereopsis  
Colour vision  
Other
24. At the vision screenings, what are the pass/fail criteria for the individual tests?  
*Please leave blank where test is not included.*

<table>
<thead>
<tr>
<th>Pass/fail criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monocular distance visual acuity</td>
</tr>
<tr>
<td>Binocular distance visual acuity</td>
</tr>
<tr>
<td>Monocular near visual acuity</td>
</tr>
<tr>
<td>Binocular near visual acuity</td>
</tr>
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<td>Distance cover test</td>
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</tr>
<tr>
<td>Stereopsis</td>
</tr>
<tr>
<td>Colour vision</td>
</tr>
<tr>
<td>Other (please specify)</td>
</tr>
</tbody>
</table>

25. Please feel free to provide further information on any vision screenings in which you have participated.  
*Please write your answer in the space below.*

Final remarks.

26. If you haven't participated in any vision screenings outside your practice, please select from the answers below which best describes you.  
*Please pick one of the answers below or add your own.*

- Not applicable
- Would like to, but don't know how to get involved
- Don't have enough time to get involved
- Would not like to get involved
- Other (please specify)

27. Any further comments.  
*Please write your answer in the space below.*