

**THE RELATIONSHIP BETWEEN 6/9 DISTANCE VISION, OTITIS MEDIA WITH
EFFUSION AND EMERGENT LETTER NAME KNOWLEDGE**

Thesis presented in partial fulfillment

of

a Master of Science in Child and Family Psychology

at the University of Canterbury

by

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August 2013

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Acknowledgements

I would firstly like to acknowledge the support I have received from my supervisors in the completion of my thesis. Dr Kathleen Liberty, Dr Brigid McNeil and Dr Arindam Basu. I have really appreciated your expertise, passion, and the generous way in which you have shared your time and knowledge with me. Without Dr. Liberty's previous research in the Children's Learning Study and extensive knowledge in this area, this research would not have been possible. I wish to thank the Asthma and Respiratory Foundation of New Zealand for the grant that supported the collection of data reported in this thesis. I would also like to acknowledge the children and families who participated in the Children's Learning Study. Finally, there are a number of people without whom this thesis might not have been written who I would like to acknowledge. To my late Nana, whose dedication for helping others has inspired me, my Mother, whose unwavering support has kept me going, Joanna, for laughing with me and Julien for always believing in me.

Abstract

Background: There is a need for more well-controlled research on the relationship between vision and hearing limitations and emergent literacy to inform early literacy intervention. Two highly prevalent difficulties of early childhood, poor distance visual acuity and otitis media with effusion (OME), have been shown to be associated with literacy achievement. There is little research, however, on the relationship between these conditions and emergent literacy.

Objective: The objective of this study was to assess the relationships between (1) distance visual acuity and emergent letter name knowledge, and (2) OME status and emergent letter name knowledge in children at school entry.

Method: A prospective cohort of children (N=298) was recruited at school entry. Participants were aged 5, did not require special education for high needs and spoke a nationally recognized language of New Zealand. Distance vision and tympanometry testing was performed and a parent report of OME was obtained. The Wechsler Individual Test of Letter Name Knowledge and the Vocabulary and Block Design sub-tests of the Wechsler Intelligence Scale for Children were administered. Covariates of reading achievement were also measured.

Results: Twenty three percent of children knew fewer than 4 letters at school entry, 31.9% had marginal distance visual acuity of 6/9 in one or both eyes and 37.2% had a history of ear infections and/or a B tympanometry test at school entry. Logistic regression tests demonstrated that both 6/9 vision (OR= 2.069, CI_{0.95}=0.999-4.227) and OME status

(OR=1.846, CI_{0.95}=1.034-3.297) were significantly associated with low letter name knowledge at school entry, controlling for covariates of emergent literacy. Another analysis showed that children with 6/9 vision and/or OME at school entry were also at greater risk for low letter knowledge (OR=2.187, CI_{0.95}=1.067 ó 4.484) than children with 6/6 vision and no OME at school entry.

Conclusions: The results of the current study indicate that 6/9 distance vision and OME are risk factors for low letter name knowledge at school entry. These factors warrant greater consideration with regard to early literacy intervention, classroom teaching practices and future research.

Chapter 1

Introduction

Vision in Early Childhood

Vision problems are highly prevalent in children, with up to 20% of children experiencing some type of vision difficulty (Ethan & Basch, 2008; Ethan, Basch, Platt, Bogen, & Zybert, 2010; Thompson & Evans, 2002). Therefore it is important the effects of limited vision upon child development are well understood (Ethan & Basch, 2008).

Common vision impairments in children include amblyopia (lazy eye), refractive error, astigmatism, strabismus (crossed eyes) and binocular coordination difficulties (Basch, 2011; Miller, Menacker, & Batshaw, 2002). In addition, a significant number of young school children have unnoticed, minor and remediable visual defects (Thomson & Evans, 2002). Children from minority ethnic groups (Ethan & Basch, 2008), low socio economic status (SES) (Ethan & Basch, 2008; Suchoff & Mozlin, 1991) and with a family history of vision problems (Williams et al., 2008) are at higher risk for developing vision problems.

In addition to the high prevalence of vision problems, vision in early childhood is typically limited as it undergoes much development from birth to reach adult levels. The vision of newborns is very immature, and their visual acuity is usually around 40 times worse than a typical adult (Maurer & Lewis, 2001). Therefore vision undergoes much development in the first years of life, including changes to the optic nerve, lens and muscles that control eye movement (Atkinson et al., 2000; Berk, 2009).

One important aspect of vision that undergoes much development throughout early childhood is visual acuity (Pan et al., 2000; Buckingham & Kelly, 1996; Maurer & Lewis, 2001). Visual acuity is the term for the sharpness, or discrimination of central vision (Berk,

2009) and is necessary to detect detail and shapes of objects. For most children, visual acuity reaches the adult standard of 6/6 by age 5 (Slater, 2002), but approximately 12 to 28.6% of children between aged between 5 and 6 years have visual acuity of 6/9 or worse (Lai, Wang, & Hsu, 2011; Pai et al., 2011; Sheridan, 1974).

Considering both the high prevalence of vision problems, and the development of vision throughout early childhood, it is clear that many children in early childhood struggle to focus their eyes well or see objects clearly. It is important that the effects of this upon development are well understood.

Hearing in Early Childhood

Bilateral and unilateral hearing loss is also very common in early childhood with a prevalence of approximately 3.1% (Erenberg, Lemons, Sia, Trunkel, & Ziring, 1999; Mehra, Eavey, & Keamy, 2009). In early childhood, the most frequent cause of hearing loss is Otitis Media with Effusion (OME) (Dhooge, 2003; Roberts et al., 2004). OME refers to the inflammation of the middle ear, where the tympanic membrane outside the middle ear is thickened, and there is fluid build-up in the middle ear (Roberts, 2003). This fluid build-up can prevent the eardrum from vibrating properly, and therefore can cause mild to moderate conductive hearing loss (Rosenfeld et al., 2004). Most children with OME experience fluctuating, mild to moderate hearing loss, usually between 15 and 40 dB (Bluestone & Klein, 2007) which can be present for a few weeks, or persist for 6 to 24 months (Teele, Klein, & Rosner, 1989). OME is typically detected through the use of tympanometry screening, which estimates pressure on the ear drum associated with OME (Gutierrez, 2012). OME is particularly common in children because the Eustachian tube, from which fluid in the ear drains, is still developing and does not drain as well as in adults (Berk, 2009). The hearing loss caused by

OME is usually temporary, but if OME occurs repeatedly, it can cause permanent hearing loss (Roberts, Burchinal, & Zeisel, 2002).

Around 75% of children experience OME before their third birthday (Alsarraff, Jung, Perkins, Crowley, Gates, 1998; Roberts, 2004; Herer et al., 2007). A smaller proportion of children (3 to 11%) experience chronic and recurrent OME in early childhood (Erenberg et al., 1999; Mehra et al., 2009). In New Zealand, approximately 7% of children fail their tympanometry screen at school entry (National Audiology Centre, 2003), which is indicative of the presence of OME, although a recent study indicated a decline associated with age in the rate of children aged 1 to 5 experiencing OME (Gribben, Salkeld, Hoare & Jones, 2012). These high rates of OME indicate that the effects of OME on child development need to be well understood. Risk factors for the experience of recurrent OME during early childhood include low SES, (Hall, Maw, & Steer, 2009; Hill, 2012), minority or indigenous ethnicity (Bowd, 2002; Hall et al., 2009; Hill, 2012; Morris & Leach, 2009) young age and male gender (Teele et al., 1989) and exposure to passive smoking at home (Hall et al., 2009). Biological and genetic differences can also predispose a child to experience frequent OME (Rovers, Haggard, Gannon, Koeppen-Schomerus, & Plomin, 2002; Wiertsema & Leach, 2009).

Reading Development

Given that learning to read requires both visual and auditory capacity (Snow, Burns & Griffin, 2001), it is possible that the visual and hearing limitations of early childhood could be associated with difficulties in literacy development. Learning to read is a fundamentally important task of childhood, and is known to be associated with academic achievement, self-esteem and school retention, among other important developmental outcomes (Brynnner,

2008; Snow, Burns, & Griffin, 1998; Stanovich, 1986). In adulthood, literacy skill is known to enhance societal inclusion and employment prospects (Torgesen, 1998). While most children learn to read without any problems, up to 10% experience significant difficulty despite otherwise having normal development (Goswami et al., 2011). It is therefore important that continued research is conducted to better understand reading development in children and factors that are associated with reading achievement (Lundberg, Larsman, & Strid, 2012).

To successfully learn to read, research has shown that children need to develop both phonological and orthographic processing skills (Cunningham, 2011). Phonological processing is the awareness of syllables, onset and rime units, and phonemes, which make up spoken words (Cunningham, 2011), while orthographic processing refers to the ability to form, access and remember the visual representations of letters and words (Cunningham, 2011). These skills have been shown to be particularly important in the early primary school years, when children are in the word decoding stage of learning to read (Storch & Whitehurst, 2002). Therefore models of reading development typically include the development of orthographic (visual) and phonological (auditory) pathways (e.g. Figure 1) as being central to the development of reading skill.

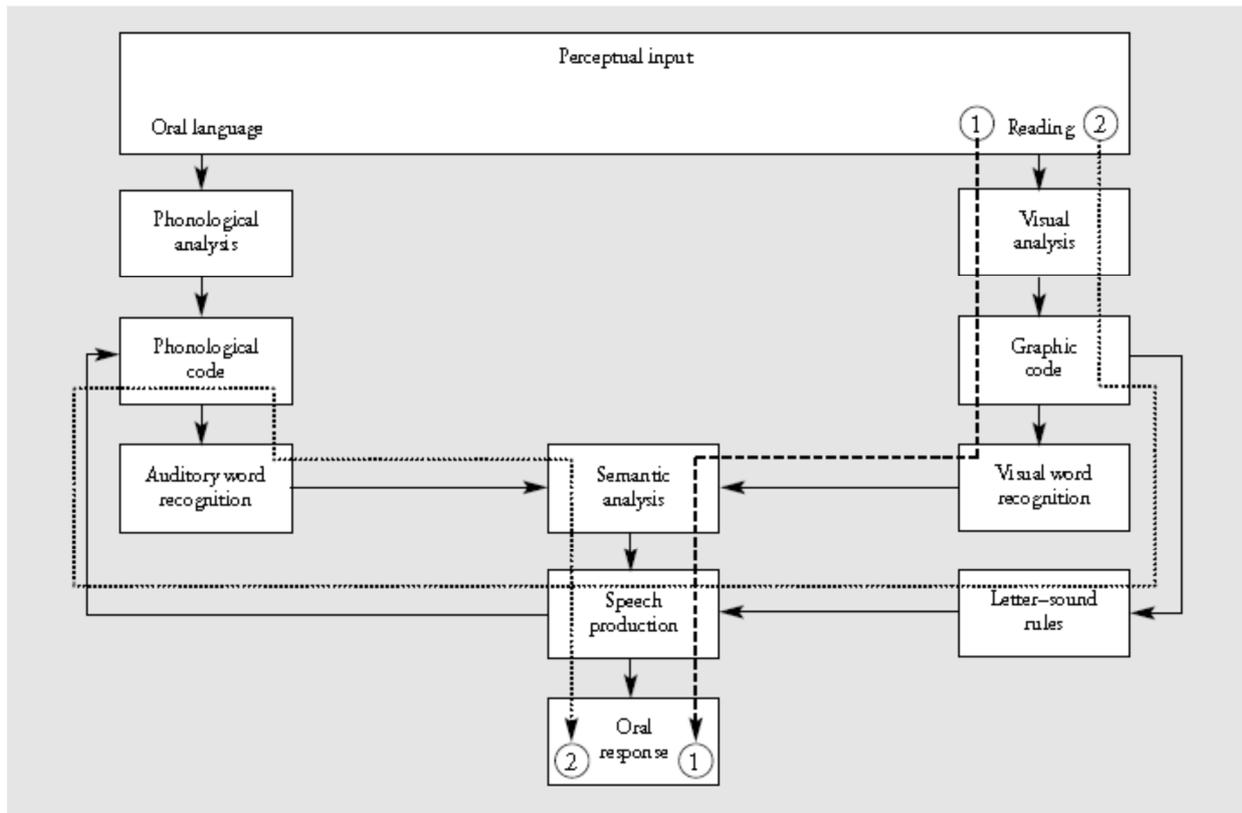


Figure 1 The phonological and orthographic pathways which are fundamental for reading development (McEneaney, Lose, & Schwartz, 2006, pg. 119).

An important limitation of this model, common to most models of reading development, is that the effects of vision and hearing problems have received little attention. The common model of reading development as illustrated in Figure 1 would indicate that the orthographic (visual) pathway begins with “visual analysis” and the phonological (auditory) pathway begins with “phonological analysis”. This model is limited because it seems to overlook the importance of the visual and hearing capacity of the reader in developing these visual analysis and phonological analysis skills. This is problematic, given that the development orthographic processing can be seen to depend on vision, as this pathway involves seeing

letters and words. Furthermore, it seems that hearing capacity would be fundamentally important to the development of phonological processing skill, which involves detecting the sounds associated with letters and words.

Emergent Literacy

Children start to develop the skills they need to learn to read very early in life, before they start school (Snow et al., 1998). Emergent literacy skills form the foundation for later reading development and become evident in early childhood (Rayner, Foorman, Perfetti, Pesetsky & Seidenberg, 2001; Sulzby & Teale, 2003; Whitehurst & Lonigan, 2001). These are a set of skills, understandings and knowledge, which help children learn to read (Burgess & Lonigan, 1998). These skills start to develop well before children begin primary school, and are considered to be the developmental precursors of reading (Lonigan et al., 1999). Important emergent literacy skills at school entry include phonological awareness, letter name and sound knowledge, rapid naming skills, vocabulary, and print knowledge (Whitehurst & Lonigan, 1998).

Emergent literacy skills at school entry predict reading achievement after controlling for other factors associated with reading achievement, such as socio economic status and ethnicity (Chatterji, 2006; Foorman, Brier & Fletcher, 2003; Torgesen, 2000; Rayner, 2001). Children who begin school with few emergent reading skills have been shown to respond more slowly to formal literacy instruction, have negative attitudes about reading and are likely to have less reading experience than their peers (Lonigan, Burgess, & Anthony, 2000). Children with poor emergent literacy skills at school entry are also more likely to develop behavioural and emotional problems in their first year of school (Kellam et al., 1999).

Early Intervention for Literacy

Given the important contribution of emergent literacy skill to later reading development, it is concerning that a substantial proportion of children possess few emergent literacy skills when they start school (Chatterji, 2006). One recent study showed that around 23% of 5-year olds in Australia had letter name knowledge and phonological awareness skills that were significantly below the expected range for their age (CCCH Telethon Institute for Child Health Research, 2009).

Fortunately, research has shown that the reading outcomes of children with poor emergent literacy skills at school entry can be improved with early intervention at the start of school (Foorman, Breier, & Fletcher, 2003). Early reading intervention aims to improve the reading outcomes of children who are at risk, before their developmental trajectory becomes one of reading failure. This is different to remedial approaches, which may wait 1 to even 3 years to provide reading intervention to a struggling child. Early reading intervention (provided between the end of preschool and the end of their second year at primary school) have proven effective, showing that many children identified with poor emergent literacy skills can develop age-appropriate reading skills given the appropriate support (Reynolds, Wheldall, & Madelaine, 2010). The successful implementation of early intervention requires the accurate identification of children at risk for having poor literacy skills when they start school. It is important that educators understand risk factors for poor emergent literacy and apply the information to prevent reading failure.

The Development of Emergent Literacy

As literacy skills start to develop early in a child's life, there are many factors that influence their development (National Reading Panel, 2000). The multiple determinants of children's early literacy skill development include both factors central to the environment and to the individual child (e.g. Chatterji, 2006; Evans, Barraball & Eberle, 1998; Fiscella & Kitzman, 2009). These include ethnicity (Nicholson, 2003; 2007), cognitive ability (Evans, Bell, Shaw, Moretti, & Page, 2006), family socio economic status (Bowey, 1995), home literacy support levels (Melhuish et al., 2008), early literacy experiences (Dickinson & McCabe, 2001), behaviour (Normandeau & Guay, 1998) and age (Chatterji, 2006; Fiscella & Kitzman, 2009).

One important factor associated with emergent literacy skill is the socio-economic status (SES) of a child's family. Children from families with less financial resources than others have been found to have lower phonological awareness and letter name knowledge skills at school entry (Bowey, 1995; Brooks-Gunn & Duncan, 1997; West, Denton, & Germino-Hausken, 2000; Whitehurst & Lonigan, 1998). SES has been found to explain more variance in poor emergent literacy than other predictors, including ethnicity, gender, personality or developmental factors (Pati, Hashim, Brown, Fiks, & Forrest, 2011). In one study, low SES was found to explain more than half of the variance in emergent literacy at school entry (Chatterji, 2006).

Children who belong to minority ethnic groups are also more likely to have low emergent literacy skills at school entry (Duncan & Magnuson, 2005). Specifically, in the New Zealand literature, M ori and Pacific Island children have been shown to enter primary school with fewer pre- reading skills than their peers (Nicholson, 2003, 2008). However, it is important to note that SES may have confounded the results of this study, as this was not

controlled for. Research from the United States found that the difference in emergent literacy between minority and non-minority children was not significant after controlling for SES (Coley, 2002). Therefore the relationship between ethnicity and emergent literacy is currently somewhat unclear, and warrants further research, particularly with regard to the New Zealand context.

Other research has shown that a child's home learning environment has a substantial effect upon children's emergent literacy (Melhuish et al., 2008). Importantly, there is literature to show that a child's home environment predicts unique variance in emergent literacy, after controlling for intelligence and SES (Bus, Van Ijzendoorn, & Pellegrini, 1995; Griffin & Morrison, 1997; Lonigan, Burgess, Anthony, & Barker, 1998; Sénéchal & LeFevre, 2003; Smith, Brooks-Gunn, & Klebanov, 1997). Specifically, aspects of the home environment that promote the development of emergent literacy skills include sensitive and nurturing parenting (Dodici, Draper, & Peterson, 2003), stimulating learning environments (Melhuish et al., 2008) and the literacy activities and experiences which a child has at home (Dickinson & McCabe, 2001). In particular, parental teaching of literacy to their children predicts children's letter identification skill at school entry (Nord et al., 2000). Book exposure (Davidse, de Jong, Bus, Huijbregts, & Swaab, 2011), frequency of shared reading (Nord, Lennon, Liu, & Chandler, 2000; Pati et al., 2011), and the number of books a child owns (Pati et al., 2011) are also associated with emergent literacy.

Both gender and age are also important. Gender is also related to early reading skill development, with females out-performing males in emergent literacy skill at school entry (Lundberg, Larsman, & Strid, 2010; Ready, LoGerfo, Burkam, & Lee, 2005). A child's age at

school entry has also been found to explain two to three percent of children's beginning reading knowledge and skills, controlling for SES (West, Denton, Reaney et al., 2000).

Cognitive abilities and behaviour problems are also associated with emergent literacy development (Evans et al., 2006; Griffin & Morrison, 1997). In particular, verbal intelligence has been found to predict emergent literacy skill development (Bowey, 1995; Lonigan et al., 2000; Whitehurst & Lonigan, 2001). Children with behavioural difficulties have also been shown to have poorer emergent literacy at school entry (Normandeau & Guay, 1998), as have children with speech and language impairments (Justice, 2006; Raitano, Pennington, Tunick, Boada, & Shriberg, 2004).

While there is also some evidence to suggest that vision and hearing problems are detrimental to emergent literacy development (Bracken & Cato, 1986; Des Jardin, Ambrose & Eisenberg, 2008; Shankar et al, 2007), an important limitation of research on the development of emergent literacy is that most studies have not reported or controlled for the vision and hearing of participants. This includes studies of the relationship between emergent literacy and cognitive ability (e.g. Evans et al., 2006; Lonigan et al., 2005), behaviour problems (e.g. Haak, Downer & Reeve, 2012), speech and language impairments (Justice, 2006), ethnicity (Nicholson, 2003), SES (Pati et al., 2011), home literacy support levels (Haak et al., 2012) and age (e.g. Fiscella & Kitzman, 2009). This is concerning, as visual and auditory input is central to learning to read (Snow, Burns & Griffin, 1998). In addition, vision and hearing problems, such as poor distance visual acuity and OME are highly prevalent in early childhood, during the period that literacy skills are beginning to emerge. Furthermore, many known risk factors for poor emergent literacy are known to also be associated with

vision and hearing problems. The implication of this is that research on emergent literacy development may be confounded by undetected and unreported vision and hearing problems.

In summary, it is clear that vision and hearing limitations are common in early childhood, as children's biological systems develop. Two common such difficulties are visual acuity problems and OME. In New Zealand, children are routinely screened at preschool or school entry (aged 4-5 years) for vision and hearing problems (VHT protocols, 2009). It is important that the relationships between vision and hearing in early childhood, and developmental outcomes are well understood so that early intervention can be provided to children who are at risk for reading problems. The evidence linking vision and hearing problems with emergent literacy difficulties is reviewed in the following chapter.

Chapter 2

Literature Review

The objective of this literature review was to critique research studies concerning the relationship between visual acuity and literacy, and OME and literacy. A review of the literature on the development of emergent literacy, the relationship between distance vision and literacy, and OME and literacy was undertaken. Research studies included in this literature review were obtained through a search of the Psyc INFO and Google Scholar databases, using the combinations of the following search terms; 'emergent literacy', 'early literacy', 'literacy', 'reading achievement', 'letter name knowledge', 'phonological awareness', 'vision', 'vision problems', 'visual impairments', 'distance vision', 'visual acuity', 'distance visual acuity', 'otitis media with effusion', 'ear infections', 'glue ear', 'screen', 'hearing loss', 'hearing impairments' and 'hearing problems.' Only studies of children, which were written in English and published in peer-reviewed journals were included in the literature review.

The Relationship between Vision Problems and Literacy

Vision problems can affect physical, cognitive, neurological and emotional development (Miller & Menacker, 2007). Specifically, research has shown that vision problems put children at risk for developmental setbacks in areas such as cognitive development (Atkinson et al., 2002; Basch, 2011; Fiscella & Kitzman, 2009; Nandakumar & Leat, 2008), including non-verbal ability (Cass, Sonksen, & McConachie, 1994) and language development (Cass et al., 1994; Das, Spowart, Crossley, & Dutton, 2010). Visual impairments are also associated with social development difficulties (Cass et al., 1994), school connectedness (Basch, 2011)

and behaviour problems (Das et al., 2010; Cass et al., 1994; Johnson et al., 1996). Studies have also shown that vision problems have a higher prevalence in children with specific learning disabilities (Nandakumar & Leat, 2008) and with poor academic achievement (Johnson, Nottingham, Strutton, & Zaba, 1996; Orfield, Basa, & Yun, 2001; Rosner & Rosner, 1997).

There is also much research to support an association between vision problems and poor literacy development. Research has shown that vision problems, including refractive error, muscle imbalance, eye movement disorders and ocular misalignment can put children at risk for poor reading outcomes (e.g. Chen et al. 2011; Kulp & Schmidt, 1996; Latvala, Korhonen, Penttinen, & Laippala, 1994; Maples, 2003; Orfield, Basa & Yun, 2001; Simons & Gassler, 1988; Young, Collier-Gary, & Schwing, 1994). Refractive error is the most common type of vision problem, and can affect visual acuity at a near, and a far distance (Basch, 2011). Refractive errors shown to be detrimental to reading achievement include hyperopia and near visual acuity problems (Kulp & Schmidt, 1996; Latvala, Korhonen, Penttinen, & Laippala, 1994; Orfield et al., 2001; Rosner, 1997), distance visual acuity problems and near sightedness (Dusek, Pierscionek, & McClelland, 2010; Orfield et al., 2001) and astigmatism (Orfield et al., 2001).

Some of the other vision conditions known to be associated with literacy achievement in children include exophoria (Simons & Gassler, 1988; Young, Collier, Gray & Schwing, 1994; (Dusek et al., 2010), hypermetropia (Stewart-Brown & Brewer, 1986; Young et al., 1994), accommodative facility difficulties, (Dusek et al., 2010; Kulp & Schmidt, 1996; Shin, Park, & Park, 2009; Young et al., 1994), convergence problems (Dusek et al., 2010; Young et al., 1994; Shin, Park & Park, 2009), binocular fusion range problems (Young et al., 1994),

aniseikonia (Gassler, 1986; Simons & Gassler, 1988; Young et al., 1994) and depth perception (Kulp & Schmidt, 1996).

Given that vision problems are known to be more prevalent in children with low SES and minority ethnicity (Ethan & Basch, 2008), and the known association between vision problems and low IQ (Atkinson, 2002), it is important to note that some studies have shown that vision problems can independently explain significant variance in reading achievement (Kulp & Schmidt, 2001; Maples, 2003). For example, Maples (2003) found that in typically developing children, aged 6 to 11, performance on a vision test was a better predictor of reading skills than both ethnicity and income. In addition, Kulp and Schmidt (2001) found an association between vision problems and reading achievement in the first year of school, after controlling for intelligence and age. Such studies show that there is support for a unique relationship between vision and reading. However, more research is required in this area to further establish a causal link between vision and literacy (Ethan & Basch, 2008).

In addition to studies that have supported a relationship between visual conditions and literacy, studies have also shown that previously undetected and untreated visual problems are more prevalent among populations of children and teenagers with reading and learning difficulties (e.g. Festinger & Duckman, 2000; Johnson et al., 1996; Maples, 2003; Orfield et al., 2001). This may indicate that minor vision difficulties, such as mild farsightedness, nearsightedness and astigmatism, which are not usually considered to be problematic for children, and may go unnoticed, can affect children's learning (Orfield et al., 2001; Festinger & Duckham, 2000; Maples, 2003; Johnson et al, 1996). This area of the literature warrants further attention.

It is also important to note that there is some inconsistency within the literature in this area. Some recent studies and reviews have concluded that there is no relationship between vision problems and literacy (Handler & Fierson, 2011; Kiely, Crewther, & Crewther, 2001) despite the contrary evidence provided by other researchers. Such research indicates that more attention should be paid to the relationship between vision and literacy.

The Relationship between Visual Acuity and Literacy in Children

Poor visual acuity can be caused by optical, neural and cortical difficulties (Buckingham & Kelly, 1996). Refractive error is the most common cause of poor visual acuity, including conditions such as myopia (nearsightedness), hyperopia (farsightedness) and astigmatism (Rogers & Jordan, 2013). However, visual acuity problems are common in preschool children who do not have significant refractive error or vision disorders (Pan et al., 2009), as visual acuity undergoes developmental change through early childhood (Buckingham & Kelly, 1996; Maurer & Lewis, 2001). Given the high prevalence of children with limited visual acuity in early childhood (Pan et al., 2009; Berk, 2009; Lai, Wang, & Hsu, 2011), it is important the effects of visual acuity on child development, and on learning to read, are well understood. Studies on the relationship between near visual acuity and literacy, and distance visual acuity and literacy are next considered.

The Relationship between Near Vision and Literacy

Research has demonstrated that near visual acuity problems are associated with both poor emergent literacy and reading outcomes in children (e.g. Rosner & Rosner, 1997; Stewart-Brown, Haslum & Butler, 1985; Williams, Latif, Hannington & Watkins, 2005). Given that reading is generally an activity that requires near vision to read books, it is not surprising that near vision problems are associated with reading achievement (Grisham & Simons, 1993).

Studies in this area have generally categorized participants by their level of refractive error. Refractive error refers to the error in the focusing of light by the eye, and is measured in diopters. Refractive error can cause reduced visual acuity or blurry vision (Berk, 2009). A person with refractive error within the diopter range of - 0.50 to +0.50 would generally be considered to have normal vision (Goh, Pokharel & Ellwein, 2005), while a person with refractive error outside this range is likely to have blurry vision.

One important study (Shankar et al., 2007) demonstrated an association between hyperopia and poor emergent literacy at age 5. Hyperopia is a visual condition caused by refractive error, which affects near visual acuity (Goh, Pokharel & Ellwein, 2005). Children were categorized by the quality of their near vision. The emergent literacy of children with refractive error of 2 diopters or worse (N=13) was compared to that of children with less than 1.5 diopters of refractive error or better (N=19). Participants were assessed by the Wide Range Achievement test (WRAT III) on the Letter and Word Knowledge and Phonological Awareness sub tests. The mean letter and word knowledge scores of children with greater refractive error were found to be one standard deviation lower than the children with lower levels of refractive error. No group differences were found for other factors, such as developmental concerns, parental education, family income, or health.

There is also evidence that near vision problems are associated with reading achievement in older children. Williams, Latif, Hannington and Watkins (2005) assessed the relationship between mild hyperopia and literacy in a cohort of children aged 8. Participants received vision testing at their entry to the study and were assessed by a standardized measure of achievement. The mean achievement of children with refractive error more than

1.25 diopters in their best eye was found to be significantly lower than that of children with less refractive error.

Rosner and Rosner (1997) also demonstrated an association between literacy and refractive error in children from first to fifth grade. The Iowa Test of Basic Skills was administered to the children and their vision was tested. Of the children with refractive error over 1.25 diopters, 13% were in the top quartile for literacy achievement, compared to 27% of children with less refractive error.

Stewart-Brown et al. (1985) also demonstrated an association between near vision and literacy reading achievement in a cohort of children, aged 10 years. A school doctor assessed the participants' vision and their reading achievement was assessed by the Edinburgh Reading Test, a standardized measure of reading. Children with near visual acuity problems were found to have a significantly lower mean reading score than children with normal near vision, after controlling for IQ, SES and gender.

Therefore, there is some evidence to support an association between near visual acuity and literacy. It is important to note, however, that other studies have shown no association between near vision problems and reading achievement (e.g. Handler, 2004; Helveston et al., 1985; Kiely, Crewther, & Crewther, 2001). Such inconsistencies indicate that more research should be conducted in this area, so that the relationship between near vision and literacy can be better understood.

The Relationship between Distance Visual Acuity and Literacy

Another type of vision problem that may be associated with literacy difficulties is distance visual acuity (e.g. Chen et al., 2011; O'Grady, 1984; Young, et al., 2004). Unfortunately, the relationship between distance visual acuity and literacy is not currently well understood, and

there is much inconsistency within the literature. Distance visual acuity refers to the clarity of vision for letters, words and other objects in the distance. Approximately 12 to 28.6% of children between 5 and 6 years have distance visual acuity of 6/9 or worse (Lai, Wang, & Hsu, 2011; Pai et al., 2011; Sheridan, 1974).

Distance vision is usually assessed through a Snellen test, where a person is required to name letters of systematically varied sizes viewed from a specified distance. Snellen notation is used to describe the quality of a person's distance visual acuity. For example, a person with 6/6 distance visual acuity is considered to have normal visual acuity, and can see at a distance of 6 metres what most other people can see from 6 metres away. Distance visual acuity of 6/9 means that someone can see from 6 metres away the same size letters that a person with typical vision can see from 9 metres away. Distance visual acuity of 6/12 means that a person needs to be at six metres to be able to see what those with typical vision can see from a distance of 12 metres.

Distance vision screening is commonly used with young children to identify vision problems that can impact on their development, such as amblyopia, strabismus and other refractive errors (Saunders, 2010). In New Zealand, vision screening is implemented for distance, and strabismus. Children with 6/12 vision or worse, or strabismus, are immediately referred to a vision specialist, while children with 6/9 vision are re-tested within 6 months (New Zealand Vision and Hearing Testing Service, 2009).

Since in New Zealand, information about children's visual acuity is readily available through the B4 School Check vision screening, a better understanding of the relationship between distance visual acuity and literacy could potentially lead to the identification of a risk indicator for early literacy intervention based on the distance vision screening test. There

is research to suggest that poor distance visual acuity is associated with poor literacy achievement (e.g. Chen, Bleything, & Lim, 2011; Grisham, Powers, & Riles, 2007; Maples, 2003; Young et al., 1994). However, there is evidence to the contrary (e.g. Dirani et al., 2010; Stewart-Brown et al., 1985; Williams, Latif & Hannington, 1998). These studies and the limitations of the literature on the association between distance visual acuity and literacy will now be discussed.

Young et al. (1994) recruited children (N=144) aged 6 to 9 from mainstream classrooms. Children were assessed with a vision test battery and information about their school achievement was gathered from their class teachers. Children's scores were used to categorise 'low', 'medium', or 'high' achievement groups. Children, whose scores placed them in the low achievement group, were found to have significantly poorer distance visual acuity than children in the high achievement group. There was also a group of children identified (N=18) who could not read after a year of instruction, whose data were analysed separately. This group of children were found to have nearly 2.5 times more vision problems than children who could read. Importantly, 95% of the children who could not yet read had distance visual acuity of 6/9 or worse. It was suggested by the researchers that distance visual acuity should be better than 6/7 for beginning readers.

Chen et al. (2011) recruited a cohort of children at age 8 (N=1103), in their second year of public school and assessed their vision using a battery of tests. Based on the results of a standardized, school examination administered at the end of their first year of school, children were categorized into a low achievement group or a normal achievement group. Of the children found to have low academic achievement by the end of their first year at school, 12% were found to have visual acuity of 6/12 or worse, in comparison to 4% of those with

average or above average achievement. This difference in visual acuity was found to be statistically significant, and therefore demonstrated further support for an association between distance vision and literacy development.

O'Grady (1984) also reported an association between distance vision and literacy. This study recruited children aged 7, in their second year of school. The children's vision was tested and their reading was assessed with the Edwards Diagnostic Reading Test. The Peabody Picture Vocabulary Test was also administered to the children as a measure of cognitive ability. Children with distance vision of 6/8 were categorised as 'normal' acuity and 6/10 was used to establish 'suspect' visual acuity. A multiple regression analysis determined that reading achievement was significantly associated with 'suspect' vision, even after controlling for cognitive ability.

Dusek et al. (2010) recruited children referred to a specialist eye care facility due to their reading difficulties. A control group consisted of age-matched peers who received routine eye examinations at the eye care facility and who had not been referred for reading difficulties. All of the participants were aged 6 to 14, of average intelligence. Children with known eye disorders were excluded from the study. The binocular distance visual acuity of children referred to the clinic for reading difficulties was compared to that of the control group. Children who were behind their peers in reading, but did not have specific reading disabilities, were found to have significantly worse visual acuity than their peers who were not poor readers.

In spite of the findings of these studies, there is also research to indicate that there is no relationship between distance visual acuity and reading performance (e.g. Helveston et al., 1985; Krumholtz, 2000; Muzaliha et al., 2012; Williams, Sanderson, Share, & Silva, 1988).

One such study (Dirani et al., 2010) assessed the relationship between academic performance and distance visual acuity in children aged 9 to 10 (N = 1143), who attended mainstream schools in Singapore. The participants underwent a comprehensive eye examination and their academic achievement was measured by a nation-wide standard academic examination. Children with known vision conditions were excluded from the study. A multiple regression analysis was performed to assess the relationship between distance visual acuity and academic achievement a year later. Both a criterion of 6/9 distance vision and of 6/12 distance vision were utilized. A significant relationship between distance visual acuity and academic achievement was not found, using either criteria, after controlling for gender, ethnicity, SES and IQ ($\beta = -0.03$, $p = 0.98$). It was concluded that distance visual acuity did not play a significant role in predicting academic school performance.

Watson et al. (2003) screened the vision of children in first grade (aged 6 and 7). Vision was screened for refractive error and accommodative and binocular functioning. Children who were referred following vision screening had a lower mean letter and word identification score than those who were not referred. However, the difference in mean scores was not statistically significant. It is important to note, however, that the relationship between visual acuity referrals and literacy was not directly assessed in this study. In addition, the referral criterion for problematic visual acuity was not reported.

Williams and colleagues (1988) recruited a cohort of New Zealand children, aged 7 and 11 years. Children's distance vision was assessed at their entry to the study and they were assigned to a group based on their result. The participants' use of spectacles was not reported. Reading skill was tested by performance on the Burt Reading Test. The mean reading scores of children in the 6/6 vision group and 6/12 group were not found to differ significantly. It

was concluded that distance visual acuity problems were not related to reading achievement (Williams et al., 1988).

An earlier study in New Zealand (Stewart-Brown et al., 1985) also did not find an association between distance visual acuity and reading achievement in a cohort of 10-year old children, in year 5 at school. Each child underwent a medical examination and their distance visual acuity was assessed. Children were classified into categories based on their visual acuity results. Their reading achievement was assessed with the Edinburgh Reading test. There was not a significant difference in the mean reading scores of children with 6/6 distance vision, 6/9 distance vision, 6/12 distance vision, or 6/18 distance vision.

Grisham, Powers and Riles (2007) recruited students, aged 15 years, from high schools. These participants were referred to the study by their schools and had been identified as poor readers. The distance visual acuity of the participants was tested at their entry to the study through a Snellen chart. Deficient visual acuity was defined as 6/12 or worse in one or both eyes. It was found that the majority of the participants (56.8%) had 6/6 acuity in both eyes, while a smaller percentage (17.2%) had 6/12 vision or worse. It was therefore concluded that distance visual acuity was not a cause of poor academic achievement. However, it is important to note that the remaining participants with poor reading achievement (26%) were found to have visual acuity between 6/6 and 6/12.

Helveston et al., (1985) also did not support an association between distance visual acuity and literacy in a large sample of children in first, second and third grades. Distance visual acuity was assessed at their entry into the study. Reading ability was assessed by teacher reports of time spent reading, the Metropolitan Reading Test, and the Iowa Test of Basic Skills. Children were grouped by their reading achievement scores. Children were

categorized according to their distance visual acuity in the better eye. Normal visual acuity was defined as at least 6/9 or better and 6/12 or worse was defined as abnormal. An analysis was performed to determine whether there was a difference in the distribution of visual acuity within the categories of reading achievement. There was not found to be a difference in the proportion of children with abnormal and normal visual acuity in the above average, average and below average readers.

The distance vision of children with reading disabilities has also been investigated, with some researchers concluding there is no relationship between distance vision and literacy in this group (Latvala et al., 1994; Muzaliha et al., 2012). For example, Muzaliha et al. (2012) recruited children with learning disabilities, aged 8 to 12, and conducted extensive vision tests. Using a cut-off score of 6/12, it was found that the majority of children (over 90%) had normal distance vision. It was therefore concluded that distance visual acuity was not associated with learning disabilities.

Limitations of the Literature on Distance Visual Acuity and Literacy

One major limitation of research on the relationship between visual acuity and literacy is the lack of consideration of potentially confounding factors (e.g. Chen et al., 2011; Dusek et al., 2010; Orfield et al., 2001; Rosner & Rosner, 1997; Young et al., 1994). This is concerning, as vision problems are also known to be associated with risk factors for poor literacy. For example, low SES is known to be a factor associated with low reading achievement (Basch, 2011), yet studies by Chen et al. (2011) and Young et al. (1994) have not considered SES in their analysis. Children of minority ethnicity are also at risk for having vision problems (Ethan & Basch, 2008), yet studies by Orfield et al. (2001) and Rosner and Rosner (1997) have not considered ethnicity in their analysis. In addition, the eye develops under

neurological control (Williams, Latif, Hannington & Watkins, 2005) and therefore it is possible that an overall cognitive or neurological deficit could explain the relationship between vision and reading. However, studies by Young et al. (1994) and Chen et al. (2011) have not considered IQ in their analysis. The one exception to this is the O'Grady study (1984), which demonstrated an association between distance vision and literacy after controlling for IQ. Due to the largely correlational nature of the research in support of an association, a direct relationship between distance vision and literacy has not been established. It is therefore fundamentally important that future research is conducted that controls for potentially confounding variables, to clarify whether there is a direct relationship between distance visual acuity and literacy.

Another limitation is that the findings on the relationship between distance visual acuity and literacy have been inconsistent. One reason for this inconsistency might be that distance visual acuity has generally been found to be associated with literacy in younger samples (e.g., Dusek et al., 2010; Young et al., 2004), but no clear relationship has been established in studies of older children (e.g. Stewart-Brown & Brewer, 1986; Williams et al., 1988; Dirani et al, 2010; Krumholtz, 2000) . This indicates that distance visual acuity may be particularly important when a child first starts school, and begins learning to read. Considering studies of older children, it is also possible that older study participants may have had remedial reading instruction to improve their proficiency at the time of the studies, since remedial reading is commonly provided to children after two or three years in school. Once a child is able to read more proficiently, the effects of distance visual acuity problems are likely to be less important (Chen et al., 2011; Grisham & Simons, 1986). Perhaps visual acuity is so important at school entry because learning to read requires the careful analysis of

letters, and the ability to discriminate between minute differences between them (Young, Collier, Gray & Schwing, 2001). It may also be due to the large amount of beginning reading that is done from a distance of 10 to 20 feet (from large books and chalk boards or white boards). More research on the relationship between distance vision and the learning to read process is warranted, given the inconsistency of the current literature.

In addition, little is known about the relationship between emergent literacy and distance visual acuity. Watson et al. (2003) found that vision test referrals, which included distance visual acuity, were not associated with emergent literacy. However, this study did not consider the unique effects of distance visual acuity, but instead the relationship between comprehensive visual screen referrals and emergent literacy. There has been some research to show that poor emergent literacy, in particular, letter name knowledge, is associated with near vision problems (Shankar et al., 2007). The relationship between distance visual acuity and emergent literacy therefore remains unclear.

There are many reasons why children with poor distance vision might have poor emergent literacy development. Firstly, children with limited distance visual acuity are likely to be less able to interact with and benefit from early formal reading instruction. Literacy activities in early childhood education generally involve the use of large books and whiteboards with large groups of children at a distance. Therefore a child with poor distance vision at preschool may be less able to discriminate the visual features of a large proportion of the letters, words and other objects in the distance presented to them. In addition, children with blurry distance vision are less likely to benefit from incidental learning. Incidental learning refers to the process by which children see words everywhere, on signboards, on the television, and advertisements (Koenig, 1996). Such incidental learning is known to help

children become familiar with the letters of the alphabet and is important for the development of letter name knowledge (Treiman, Tincoff, & Richmond-Welty, 1997). Furthermore, children with poor distance vision may experience much fatigue and struggle to pay attention to blurry appearing letters in stories, or early literacy activities, which is likely to be detrimental to their development of letter name knowledge.

Another limitation of the current literature is that the degree of visual acuity that creates risk for low reading achievement is currently unclear. The majority of investigations that have studied the relationship between distance vision and reading achievement have used a 6/12 cut-off (e.g. Chen et al, 2002; Grisham et al., 2007; Hevelston et al., 1984; Maples, 2003). The score of 6/12 is also used as a cut-off for referral, as a child with 6/12 distance vision is considered likely to also have near visual acuity problems (Orfield, Basa & Yun, 2001). However, the use of a 6/12 cut-off in distance vision testing does not always identify vision problems which may result in strain and blurring, and cause difficulty in the beginning reader (Orfield et al., 2001). Therefore it is possible that a different cut-off, such as 6/9 could more accurately identify children with vision that might impact on beginning literacy. The use of a 6/9 cut-off has received little attention, although Orfield et al. (2001) recommended the consideration of a 6/9 cut-off and O'Grady (1984) used a 6/10 cut-off. Given that research on other vision problems has shown that minor vision problems can affect the reading process (Johnson, Nottingham & Zaba, 1996; Orfield, Basa & Yun, 2001), the relationship between 6/9 vision and literacy is an important area of future research.

There are many reasons that a child with 6/9 vision might be at risk for poor literacy development. Children with 6/9 distance vision may be more likely to have both blurry distance and near vision, and experience more visual symptoms such as fatigue, strain and

attention difficulties than their peers with 6/6 vision (Horowitz, 1994; Orfield et al., 2001; Young et al., 1994). They may also have discrepancy between the acuity of each eye, with one eye with 6/9 and 6/6 in the other, which has been shown to be detrimental for early reading development (Simons, 1993; Young et al., 1994). This discrepancy can make it difficult to follow the words along in a sentence and to go from the end of one sentence to the start of the next. These problems might make it difficult to discriminate the visual features of letters, words and other objects both near and in the distance at the early stages of learning to read, which may be detrimental to early literacy development.

A final consideration has been the lack of research into literacy and distance visual acuity development. Considering that throughout early childhood, an important period for emergent literacy development, there is much variation within children's visual acuity development (Pai et al., 2011; Van Hof-Van Duin & Mohn, 1986), it is possible that there is a relationship between the development of visual acuity and emergent literacy.

In conclusion, there is some evidence to suggest that both near and distance visual acuity problems are related to literacy development in young children (Shankar, Evans & Bobier, 2007; Rosner & Rosner, 1997; Williams, Latif, Hannington et al, 1988; Dusek, 2010; Young et al., 2000; Chen et al., 2011). A pattern in the literature seems to have been demonstrated, as distance visual acuity has been shown to have a more detrimental effect upon the literacy development of younger children, who are learning to read, than on the literacy development of older children. In addition to the role of age, inconsistent results may be due to the failure to control for confounding factors, such as SES, ethnicity and home learning environments, as well as possible remedial reading instruction of older participants. Major limitations of research in this area include the lack of well-controlled studies and the

lack of clarity as to the quality of visual acuity that puts literacy development at risk. There is also a lack of research on the relationship between distance visual acuity and emergent literacy. More research is warranted in this area.

The Relationship between Hearing Problems and Literacy

The sense of hearing is essential for the development of language (Herer et al., 2007) and therefore the effects of hearing problems on a child's development can be widespread.

Congenital and permanent hearing impairments negatively affect a child in the areas of language development and speech delay (Gifford, Holmes, & Bernstein, 2009), educational outcomes (Bess, McKingley, & Murphy, 2002; Khairi Md Daud, Noor, Rahman, Sidek, & Mohamad, 2010; Tharpe, 2008), emotional and social development (Herer et al., 2007) and reading achievement at school (e.g. Colin, Magnan, Ecalle, & Leybaert, 2007; DesJardin, Ambrose, & Eisenberg, 2009; Harris & Beech, 1998; Miller, Bergeron, & Connor, 2008).

Children with hearing problems are at risk for poor reading achievement in later school years (Beal-Alvarez, Lederberg, & Easterbrooks, 2012; Lederberg, Schick, & Spencer, 2012). As early as preschool, children start to show difficulties with early literacy skills and the gap continues to widen with age (Beal-Alvarez et al., 2012). It is thought that the lack of access to phonological information due to hearing loss is the major contributor to low literacy rates in this population of children (Perfetti & Sandak, 2000).

There is also some evidence to suggest that hearing problems in early childhood can affect the development of emergent literacy skills (Andrews & Mason, 1986; Bracken & Cato, 1986; Most, Aram, & Andorn, 2006). One study compared the emergent literacy of children aged 62 to 84 months, with moderate to severe pre-lingual hearing loss, to that of typically developing children without hearing loss. Of the hearing impaired children, all used

sensory aids such as hearing aids and cochlear implants, some used spoken language and others used communication devices. The children with hearing loss were found to have lower scores than their peers on phonological awareness and letter identification (Most et al., 2006). These findings have been supported by other studies (e.g. Bracken & Cato, 1986; Andrews & Mason, 1986). Bracken and Cato (1986) found that children with hearing loss scored two standard deviations below their typically developing peers on measures of pre-reading, while Andrew and Mason (1986) found that children of normal intelligence with severe to profound hearing loss showed very little knowledge about letter and word identification in comparison to their hearing peers.

The Relationship between Otitis Media with Effusion and Literacy

The most common cause of childhood hearing loss, Otitis Media with Effusion (OME), is a condition of middle ear inflammation that can cause temporary, fluctuating, conductive hearing loss (Bluestone & Klein, 2007; Robb & Williamson, 2012). It is important that the developmental effects of OME are well understood, as 3 to 11% of young children experience chronic and recurrent OME (Erenberg et al., 1999; Mehra et al., 2009).

Audiometry and tympanometry screens are used to screen children for OME and other hearing problems (New Zealand Vision Hearing Testing Service, 2009; 2004). Children are referred to a general practitioner if their B4 School Check screening result is a $\delta B\delta$ which is strongly indicative of OME (New Zealand Vision Hearing Testing Service, 2009). For children with severe, or chronic OME, treatment options can involve antibiotics and surgical intervention with grommets (Toros & Kalaycik Ertugay, 2011). However, if a child does not have speech, language or learning problems, or significant levels of hearing loss, current

medical guidelines recommend that clinicians should manage OME with 'watchful waiting' for at least 3 months (Rosenfeld et al., 2004).

There is currently little consensus as to whether the experience of frequent or chronic OME increases a child's risk for developmental difficulties (Herer, Knightly & Steinberg, 2008; Roberts & Burchinal, 2004). Research has suggested that recurrent OME in early childhood is related to poor expressive and receptive language (Paradise et al., 2000; Roberts & Wallace, 1997), low verbal cognition (Lindsay, Tomazic, Whitman, & Accairdo, 1999; Paradise et al., 2000), poor academic achievement (Roberts et al., 1986; Silva, Kirkland, Simpson, Stewart, & Williams, 1982), and behaviour problems (Roberts, Burchinal, & Clarke-Klein, 1995; Silva et al., 1982). It is therefore important that more research is conducted on the effects of this highly prevalent condition.

Research on the relationship between OME and literacy development has been somewhat inconsistent (Lous, 1995; Roberts et al., 2004) and a clear causal relationship between otitis media and later problems in achievement has not yet been established (Williams & Jacobs, 2009). Although many studies and reviews have concluded that OME is unrelated to reading development (Lous, 1995; Luotonen, Uhari, Aitola, Lukkaroinen, & Luotonen, 1998; McCormick, Johnson, & Baldwin, 2006; Roberts et al., 2004; Roberts et al., 1989), there is also evidence to suggest that chronic OME is related to poor emergent literacy, and later reading achievement at school (e.g. Golz et al., 2005; Roberts et al., 2000; Walker & Wigglesworth, 2001; Winskel, 2006).

This review will firstly consider the relationship between a history of OME and literacy. This is the area which has received the most attention in the literature. Fewer studies, however, have been conducted on the relationship between concurrent OME and literacy,

which will be discussed. The limitations of the current literature on the relationship between OME and literacy will then be discussed.

The Relationship between OME History and Literacy

Gravel, Wallace and Ruben (1995) recruited fourteen children from a clinic and assessed them monthly with tympanometry and otoscopy during their first year of age. All episodes of OME were treated by a nurse. Children were assigned to one of two groups, depending on their OME history. They were assigned to an OME negative group if they were found to be OME free in 80% of visits during their first year of life, and the OME positive group if they had a B tympanometry result in at least 30% of their first year visits. The Letter and Word Identification sub test of the Woodcock Johnson Reading test was then administered to children at age 6. Their hearing was also assessed at this point. Despite having normal hearing at school entry, the mean Letter and Word Identification score of children in the OME positive group was one standard deviation lower than that of the OME negative group.

Further in support of an association between OME and literacy, Winskel (2006) conducted a study on the relationship between OME and reading in children aged from 6 to 8 years. Information about the OME experience of the participants was based on parental recall and medical records. Children who had experienced 4 or more episodes of OME before the age of 3 were assigned to the OME group (N=43). Children were placed in the comparison group if they had experienced none, or at most, one episode of OME before age 3 (N=43). Children in the OME group were matched with children in the control group on classroom, age and gender and SES. Children with current OME or colds were excluded from the study. The hearing of the participants was tested and found to be normal at their entry into the study. Participants were assessed by the Gray Oral Reading Test, which consists of 14 reading

passages, and the Alliteration, Rhyme and Non-Word sub tests of the Phonological Assessment Battery. The children in the OME history group were found to have Reading scores, as well as Rhyme and Non Words sub test scores that were a standard deviation lower than children without an OME history.

Updike and Thornburg (1992) also demonstrated a relationship between OME and literacy. Children aged 6 and 7 were recruited through specialist hearing clinics. Their OME histories were obtained through medical records and parent report, and their reading was assessed. Chronic OME was defined as 3 or more OME episodes during any single year from age 0 to 2. Children with chronic OME were matched on age, gender, SES and receptive vocabulary with children who had no history of middle ear problems. Children in the recurrent OME group were found to have significantly lower reading achievement scores than their matched peers.

Kindig and Richards (2000) also reported an association between OME and literacy in a sample of children (N=40) from third, fourth and fifth grade (aged between 8 and 11). Children in the OME group were identified by a paediatric otolaryngologist as having had four or more OME episodes before the age of 3. Children in the control group were recruited through public schools. These children were required to have experienced one or less OME episodes before age 3. Each child from the OME group was matched on gender, age and SES with a child from the control group. Children were assessed on two measures of word recognition. The group of children with a history of early OME were found to have word recognition scores that were approximately two-thirds of a standard deviation lower than the control group. It is important to note that children in the OME group were also found to have

significantly lower verbal comprehension, as measured by the Wechsler Intelligence Scale for Children-Revised.

Golz et al. (2005) also reported an independent relationship between a child's history of OME and early reading skill in children aged 6.5 to 8.5. This study recruited children through health clinics, which they were attending due to recurrent or severe OME. Children who had experienced at least 10 episodes of OME and had an average hearing loss of at least 25 dB before the age of 5 were placed in the OME group. The OME history of the participants was obtained through the medical records of the participants. Participants for the control group were recruited through schools, and were matched on age, grade level, gender and SES. Children's hearing was assessed at their entry into the study. Of the OME group, 30% still had some hearing impairment, while the children in the control group had normal hearing. Reading was assessed with five specifically designed reading tests that were administered by a special education teacher twice over a two-year period. The average percentage of mistakes made by the OME group on these tests was almost two standard deviations higher than that of the control group. With regard to the applicability of this study to children learning to read in English, however, it is important to note that this study was conducted with children who spoke Hebrew.

Teele et al. (1990) recruited children who attended a paediatric clinic from OME before the age of 3 months. The children's experience of OME was assessed monthly and their reading was assessed at age 7, with the Metropolitan Achievement Test. Children with fewer than thirty days with OME from age 0 to 3 were found to have significantly better reading achievement at age 7 than children who had spent 130 or more days with OME from age 0 to 3, after controlling for SES, intelligence, age and gender (Teele et al., 1990).

Roberts et al. (2000) considered the effects of OME on the development of emergent literacy in a longitudinal study. The participants for this study were recruited at birth and attended a research day care program. They were African American children and predominantly of low SES. Their OME status was examined frequently (weekly to biweekly) with a tympanogram from 6 months to age 5 from their entry into the study. Emergent literacy skill was assessed with the Incomplete Words and Letter-Word Identification subtests of the Woodcock Johnson Reading Test, which was administered within two weeks of the child's 5th birthday. Multiple regression analyses which controlled for gender, SES, maternal education, quality of home and child care environments showed that the percentage of time with OME-related hearing loss during early childhood was a predictor of scores on the Incomplete Words sub-test, but not the Letter-Word sub-test. However, total duration of OME was not associated with scores on either sub-test.

In another somewhat inconclusive study, Luotonen et al. (1998) recruited children aged 8 and 9 years from primary schools. Information about the OME history of the participants was gathered through questionnaires sent to the children's parents. The children's teachers were asked to report on the school achievement of the participants. The participants were grouped according to the number of OME episodes experienced in early childhood. A logistic regression analysis was performed to assess the relationship between OME and school achievement. Recurrent OME before age three was found to put boys, but not girls, at risk for low performance in reading, after controlling for maternal education, daycare attendance and the child's birth order. No association was found between school achievement and the experience of OME after the age of three.

It is important to note that the effects of OME on literacy development are long lasting. Bennett, Haggard, Silva and Stewart (2001) conducted a longitudinal study of the effects of OME from age 5 until age 9. The participants of the study were a cohort recruited at birth. Children received an otological examination every two years from age 5 to 15. Their reading achievement was also assessed with the Burt Reading Test at ages 11, 13, 15 and 18 years. Children were assigned to one of seven groups based on the severity of the OME at each examination. Regression analyses demonstrated that OME between ages 5 and 9 significantly explained reading achievement between ages 11 and 18, controlling for SES and gender.

Additional research has reported no association between OME and literacy (e.g. Luotonen et al., 1998; McCormick et al., 2006; Roberts et al., 2002). Lous (1995) reviewed earlier studies on the relationship between OME and reading, and concluded 'the correlations between reading score and OME that have been found are so small that they have no practical importance for the average child (pg. 117)'. Some more recent studies have also reported no relationship between OME and literacy. A study by Roberts and others (2002), using the same methodology as Roberts et al. (2000) assessed another cohort of children at age 4. Performance on the Letter and Word Identification and Incomplete Words sub-tests was not related to the percentage of days with either OME related hearing loss, or with OME.

McCormick et al. (2006) also recruited children from birth and assessed their middle ear functioning with tympanometry every two to four weeks from infancy till age 3. The parents of children with a tympanogram result indicative of OME in three consecutive visits were encouraged to see a physician. At age 7, children were assessed with a range of standardized and commonly used assessments tools, including the Iowa Tests of Basic Skills,

the Woodcock Reading Mastery Tests, and the Woodcock-Johnson Tests of Achievement. No significant relationship was found between the percentage of days with bilateral OME from age 0 to 3 and reading achievement at age 7. Reading achievement was found to be more strongly associated with ethnicity, home environment and SES than days of OME before age 3 years.

The Relationship between Concurrent OME and Literacy

In comparison to the literature on OME history and literacy, there is considerably less research on the association between current OME and literacy development. Only two studies were identified by the current literature review.

Walker and Wigglesworth (2001) reported an association between current OME or OME within the past year and children aged between 5.5 years and 6 years. This study was conducted with Aboriginal children in Australia in their first year of school (N=19). These children were assessed by tympanometry, otoscopy and pure tone audiometry at their entry to kindergarten or entry to school, dependent on age. Children were assigned to the OME group if they had a tympanogram indicative of OME in either or both ears, and hearing loss, either at kindergarten or school entry. Their reading was assessed at school entry by the Freebody and Byrne Word Reading Task, which measured the children's ability to read irregular, regular and nonsense words. Phonological awareness was assessed by the Preschool Inventory of Phonological Awareness Test (PIPA). Although the sample size of this study was too small for statistical analyses to be performed, children in the OME group had lower median scores on all of the sub-tests of the Word Reading and Phonological Awareness assessments.

Lous (1990) also reported a relationship between concurrent OME and literacy. This study recruited typically developing children aged 6.5 to 8.5 from schools. At their entry into the study, the children's OME status was assessed with tympanogram testing and their phonology skills were tested. Children with type B tympanograms in one or both ears had the lowest mean score on the Phonology test. In the regression analysis, this relationship held, even when controlling for sex, handedness, SES and attendance at day care.

In conclusion, while there is much research to support a relationship between OME and children's literacy (e.g. Bennett, Haggard, Silva, & Stewart, 2001; Golz et al., 2005; Gravel et al. 2005; Walker & Wigglesworth, 2001; Lous, 1990), there is also, however, evidence to the contrary (e.g. McCormick et al. 2006; Roberts et al., 2000).

Limitations of the Literature on OME and Literacy

One central limitation of this literature is that many of the studies which have found a relationship between OME and literacy are not readily applicable to the general population of children. Two such studies (Roberts et al, 2000; Walker & Wigglesworth, 2001) were conducted with children of minority ethnicity and low SES families. Therefore the findings of these studies are not readily applicable to the general population. Other studies have recruited children through clinic referrals for persistent OME (e.g. Gravel et al., 2005; Kindig & Richards, 2000; Updike & Thornburg, 2000). This is problematic because research with children who have presented for early intervention or other services may be biased toward those experiencing particularly significant difficulties. Therefore future research should assess the relationship between OME, emergent literacy and reading achievement in children more representative of the general population.

Another limitation is that some studies in this area have not reported the status of the participant's OME and hearing at the time of the literacy assessment (e.g. Gravel & Wallace, 1990; Kindig and Richards, 2000; Roberts et al., 2000; Teele et al., 1990). This is concerning, as children who experience OME in their early years are at higher risk to develop OME again at a later age (Silva et al., 1982). Furthermore, if OME occurs repeatedly, it can cause permanent hearing loss (Roberts, Burchinal & Zeisel, 2002). It is possible that concurrent OME or hearing loss associated with OME confounded the results of the studies. Only Lous (1990) and Walker & Wigglesworth (2001) assessed the relationship between concurrent OME and reading, and both of these two identified studies demonstrated a relationship. Future research should assess the hearing of the participants at the same time as their literacy, so that the relationship between OME history, concurrent OME and literacy development can be better understood.

Furthermore, a limitation of this research is the failure of studies to control for important covariates of reading achievement, including language development and IQ (e.g. Gravel et al., 1995; Walker & Wigglesworth, 2001; Winskel et al, 2006). This is concerning, as children with an early history of OME have been shown to have significantly lower reading and Verbal IQ scores (e.g. Kindig & Richards, 2000). Therefore it is possible that language delay or low IQ could explain the relationship between literacy and OME. Many other studies have been conducted on the presumption that literacy is associated with OME through the mechanism of language problems (Roberts et al. 2004), and therefore have assessed the relationship between literacy and OME during periods of critical language development. It is possible however, that OME is more directly associated with literacy development. For example, Mody, Schwartz, Gravel & Ruben et al. (1999) suggested that

recurrent OME could lead to the development of fuzzy phonological categories and subsequent poor literacy development.

Another important limitation with regard to the New Zealand context is that little is known about the relationship between OME, ethnicity and literacy. OME is highly prevalent in Māori and Pacific Island children (Hill, 2012), and children of Māori and Pacific Island ethnic groups are known to have poorer literacy achievement than their European peers (Nicholson, 2003; 2004). The higher rates of OME in indigenous populations are likely to be explained by a number of factors, including genetic predisposition (Wiertsema & Leach, 2009) and anatomical differences, such as differences in Eustachian tube functioning, which can interfere with middle ear ventilation (Beery, Doyle, Cantekin, Bluestone, & Wiet, 1980). It is possible that the higher rates of OME in children of Māori and Pacific Island ethnic groups mediate the low achievement of these children. Further research on this topic could be an important step toward understanding the literacy outcomes of children of Māori and Pacific Island children.

In addition, many studies on the relationship between OME and literacy are lacking in ecological validity. In order to accurately document the effects of OME, some studies have recruited children at a young age, and monitored their OME status from once every three months, up to once a week throughout early childhood, providing treatment when necessary (e.g. Golz et al., 2005; McCormick et al., 2006; Roberts et al., 2000; Roberts et al, 2002). However, this methodology is not representative of the care that young children with OME actually receive. Many children do not show symptoms of OME and do not always receive a diagnosis or treatment straight away (Bluestone & Klein, 1990; Roberts & Medley, 1995). It is possible that the frequent OME screening, and subsequent higher rates of treatment in these

studies could have mitigated the effects of OME. Future research should aim to consider the effects of OME with typical health care and OME monitoring.

Another major limitation of this research is that the relationship between OME and emergent literacy has received little attention. Most studies have been conducted with children aged 6 and older, after children have started reading instruction. Only three studies have assessed the relationship between OME and emergent literacy (Roberts et al., 2000; Walker & Wigglesworth, 2001) and the results have been inconsistent. This inconsistency is likely to be related to the methodological differences in these studies. The lack of research on the relationship between OME and emergent literacy is concerning, as OME is highly prevalent during early childhood, while literacy skills are starting to develop. It is important that more research should be conducted in this area to inform the effective implementation of early emergent literacy intervention.

Another area of research in need of further attention is with regard to the mechanism through which children with OME come to have poor literacy. There are many possible mechanisms that could explain the relationship between OME and literacy. Firstly, OME causes mild to moderate hearing loss, which can make it difficult to hear the sounds at the beginning and ends of words and letters, which is a crucial skill in beginning reading (Friel-Patti, 1990; Roberts et al., 1991; Rosenfeld et al., 2004). Another important mechanism might be that children with a history of OME have been shown to have poorer phonological awareness (Lous, 1990; Walker & Wigglesworth, 2001) and auditory processing skills (Aithal, Yonovitz, & Aithal, 2008; Klausen, Moller, Holmefjord, Reister & Abjornsen, 2000; Schilder, Snik, Straatman, & van den Broek, 1994). This is likely to be detrimental to reading development because children will have difficulty discriminating sounds in words or

discriminating the names of letters (c.f., öm and ö). Finally, children with a history of recurrent OME are less able to focus attention on auditory events when there is competing background noise (Bourland-Hicks & Tharpe, 2002; Klausen et al., 2000). This indicates that these children might struggle to pay attention during shared reading and teacher demonstrated instruction, which are commonly used in reading instruction, and thus could affect their literacy development. This is particularly concerning given that background noise is a common feature of new entrant classrooms. Knowledge about the mechanism through which OME may be associated with poor literacy is important for intervention and therefore this area warrants further attention.

In conclusion, although there have been many studies conducted in this area, the literature to date on the relationship between OME and literacy is somewhat inconclusive, with some studies in support of an association between OME and literacy (e.g. Gravel et al., 1995; Kindig & Richards, 2000; Lous, 1993; Luotonen et al., 1998; Teele et al., 1990; Wallace & Hooper, 1997), and others not in support (e.g. McCormick et al., 2006; Nittrouer, 1996; Roberts et al., 2004; Roberts et al., 1989). Limitations of the literature include the inconsistent findings, and the lack of research on the relationship between emergent literacy and OME, as well as on the association between literacy and concurrent OME. It is important that the relationship between OME and literacy receives more attention, due to the high prevalence of the condition.

Literacy, Distance Vision and OME

This literature review demonstrated that there is support for a relationship between both literacy and distance vision and literacy and OME in some groups of children (e.g. Dusek et al., 2010; Lous, 1990; Roberts, 2000; Teele & Klein, 1990; Young et al., 2001). There is also

some evidence that other vision and hearing problems are related to emergent literacy development (Bracken & Cato, 1986; Des Jardin, Ambrose & Eisenberg, 2008; Shankar et al., 2007). There is a lack of research, however, on the relationship between emergent literacy and distance vision, and only limited research supporting an association between emergent literacy and OME (Roberts et al. 2002; Walker & Wigglesworth, 2001).

This is concerning, given that during early childhood, while literacy skills are beginning to emerge, children are highly vulnerable to experience these conditions. In New Zealand, children's 6/9 distance visual acuity and OME are screened for at school entry. Therefore, if an association between these conditions and difficulties in emergent literacy was known of, an early literacy intervention could be provided for these children before they got behind in their reading. The purpose of the current study was therefore to examine the relationship between 6/9 distance vision, and OME and emergent literacy, in New Entrant children.

Research Questions

- 1) Is low letter name knowledge related to 6/9 distance vision in one or both eyes? Is this relationship maintained when controlling for covariates of emergent literacy?
- 2) Is low letter name knowledge related to a history of OME or concurrent OME? Is this relationship maintained when controlling for covariates of emergent literacy?
- 3) What is the relationship between 6/9 distance vision, OME status and low letter name knowledge? Are these relationships maintained when controlling for covariates of emergent literacy?

The known covariates of emergent literacy include variables both at a background level and individual child level. Background variables associated with emergent literacy include SES (West, Denton, & Germino-Hausken, 2000), home learning environment (Melhuish et al., 2008) and ethnicity (Nicholson, 2003; 2007). Individual child factors known to be related to emergent literacy include cognitive ability (Evans et al., 2006), speech and language difficulties (Justice, 2006), frequency of shared reading at home (Nord, Lennon, Liu, & Chandler, 2000) and behaviour (Normandeau & Guay, 1998). Therefore these variables were selected as covariates in the present study.

Letter Name Knowledge

One important emergent literacy skill that could be affected by both OME and distance vision problems is letter name knowledge. Letter name knowledge refers to the ability to visually recognize and verbally name the letters of the alphabet, and is one of the most important emergent literacy skills (Lonigan, Schatschneider, & Westberg, 2008; Storch & Whitehurst, 2002; Whitehurst & Lonigan, 2001) and has been shown to be a robust predictor of reading achievement (De Jong & Olson, 2004; Denton & West, 2002; Foulin, 2005). One study found that letter name knowledge was a better predictor of reading achievement than other important predictors of reading achievement, including phonological awareness, letter sound knowledge, home literacy levels, ethnicity and SES (Share, Jorm, Maclean & Matthews, 1984).

Letter name knowledge is an important predictor of reading achievement for a number of reasons. It allows children to recognize words quickly and accurately (Booth, Perfetti, & MacWhinney, 1999), decreases the memory burden of learning to read (Cardoso-Martins, Mesquita & Ehri, 2011) and promotes the use of comprehension skills in beginning readers

(Castles & Nation, 2008). Given the importance of letter name knowledge to reading development, it is clear that research on the development of letter name knowledge is fundamentally important.

There is reason to suggest that OME and 6/9 distance vision might explain low letter name knowledge at school entry. Visual acuity problems could interfere with a child's ability to discriminate letters and to be able to distinguish their shapes, thus leading to difficulty in letter name knowledge (Woodrome & Johnson, 2009). Additionally, any hearing loss associated with OME could lead to difficulties with discriminating, storing and mapping the names of letters onto their visual form. However, there is not yet conclusive evidence to support a relationship between distance visual acuity and letter name knowledge, or between OME and letter name knowledge. While research has shown that there is a relationship between near vision and letter name knowledge (Shankar, Evans & Bobier, 2007), no studies have been conducted specifically to determine the relationship between distance vision and letter name knowledge. Studies have been conducted on the relationship between letter name knowledge and OME (e.g. Gravel et al., 1995; Roberts et al., 2000), but the findings have been inconsistent and are unlikely to generalize. Therefore, letter name knowledge was selected as a measure of emergent literacy in the present study.

Chapter 3

Method

Overview

A community cohort of children was recruited at school entry, in Christchurch, New Zealand. The participants of this study were recruited between 2005 and 2009, as part of *The Children's Learning Study*. Ethical approval for the Children's Learning Study was obtained from the National Health Research, and University of Canterbury Human Ethics Committees. At their entry into the study, each child completed individual assessments with a research assistant. In addition, routine vision and hearing tests were administered by the Vision Hearing Testing service and the results of these were obtained by the researchers. The children's parents/caregivers completed a questionnaire in a face-to-face interview with the research assistant. The child's new entrant teacher, who did not know the objectives of the study, also completed a questionnaire about the child.

Design

Data obtained in the Children's Learning Study which was not previously analyzed or reported was analyzed to identify whether children with 6/9 distance vision, or past/current OME had significantly lower letter name knowledge at school entry. The inclusion of covariates in the data analyses allowed for potentially confounding factors related to emergent literacy to be controlled for.

Recruitment

New entrant pupils from eight schools in the Canterbury area were recruited over two years, beginning in 2005. These schools were randomly selected for invitation into the study from a list of all of the schools in the Canterbury area, stratified by high, mid and low decile ranking, provided by the Ministry of Education. Initially, 11 of these schools were invited to participate in the study but consent was obtained only for these 8 schools. The three declining schools did so for the following reasons: they were already involved in reading research in Year 1 classrooms (N=1), there was a lack of permanent staff in their new entrant classrooms (N=1) or they perceived that participation would lead to no benefit for the school (N=1).

Participants were recruited into the study successively upon school entrance. The recruitment process and retention of participants is outlined in Figure 2. When an eligible child entered the new entrant classroom, school staff offered their parents or caregivers information about the study. Children and families who met the following recruitment criteria were invited to participate in the study. Firstly, they were required to enrol at school on their 5th birthday or the next available school day. This criterion allowed for the control of the age of the children, which has been found to predict a small amount of variance in the beginning reading skills of children aged 4 to 5 (Hindman, Skibbe, Miller, & Zimmerman, 2010; West, Denton, Reaney et al., 2000). The second criterion was that the child did not require special education for high needs, including intellectual disability, cerebral palsy and autism. To be included in the study, children were also required to speak a nationally recognized language of New Zealand (Te Reo M ori and English). All eligible children were invited to participate in the study.

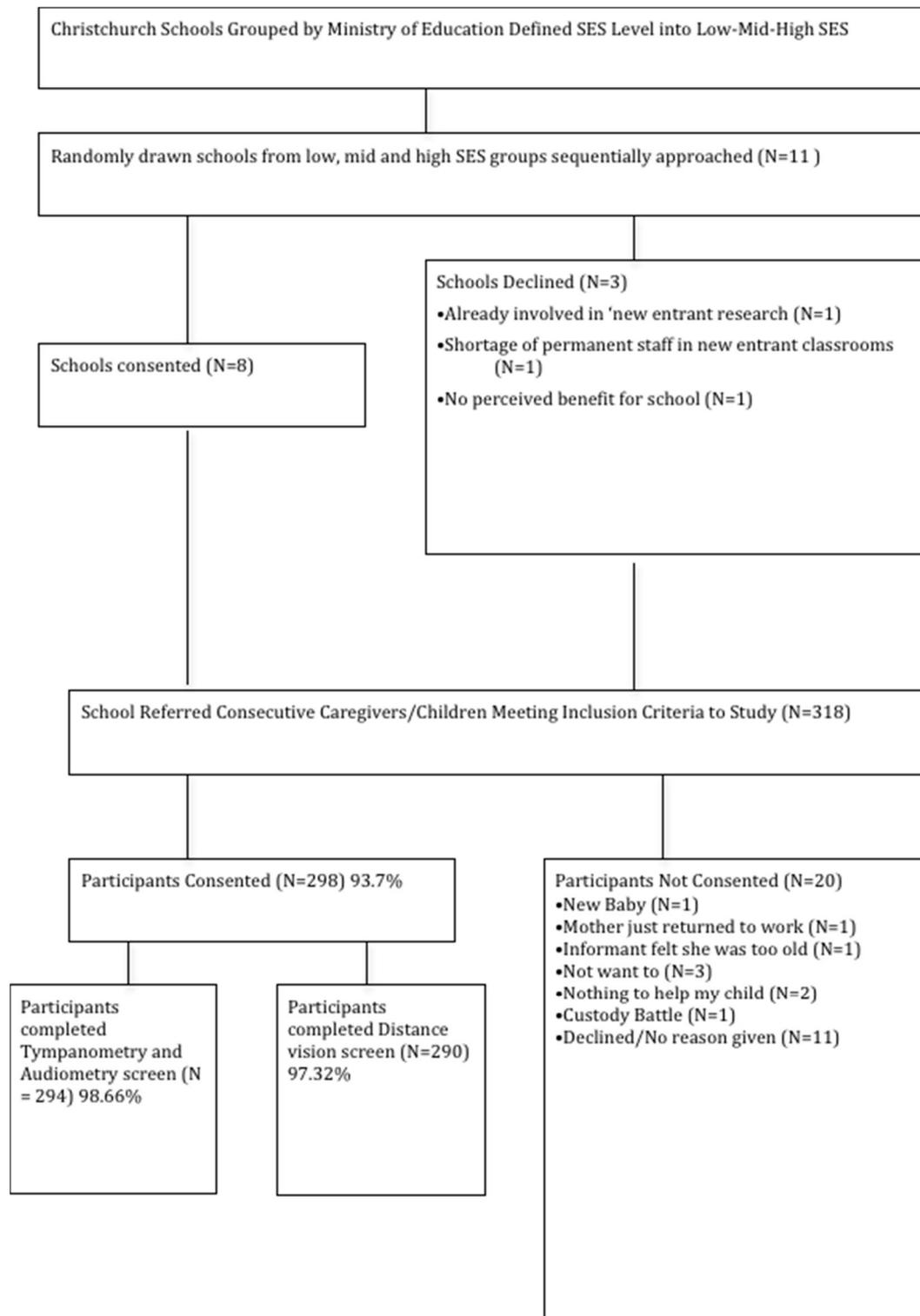


Figure 2 Recruitment procedure

Thanks to Liberty, Pattermore, Reid & Tarren-Sweeney (2010)

Participants

The child participants (N = 298) were new entrant pupils of 8 different schools in Christchurch City. The corresponding adult participants were all primary caregivers to the child in the study and were all the biological parents of the children, with the exception of five participants (two biological grandparents, one uncle, one foster parent and one adoptive parent).

Assessments and Measures

Child assessment. The measures were individually administered to children, either at their homes or at school, at their parents' discretion. Their parents were present throughout the assessment, either in another room, or seated behind the child, out of the child's line of sight.

Letter name knowledge. The letter naming items from the *Wechsler Individual Achievement Test - Second Edition* (Wechsler, 2007a) Word Reading sub-test were administered as a measure of letter name knowledge. The WIAT- II is a standardized achievement test that is administered individually with children. The WIAT-II is used commonly to assess academic skills and pre academic skills. It was designed for use with individuals within the age range of 4 years through to adulthood. The letter naming items from this sub test have been recommended as an appropriate measure of letter name skill in Grade 1 children (Rathvon, 2004). This assessment required children to verbally name the 26 lower case letters of the English alphabet, which were presented individually in non-alphabetical order on stimulus cards. According to the standard directions for administration, if participants answered 7 consecutive items incorrectly or were unable to answer 7 consecutive items, the test was discontinued. One point was scored per letter correctly named, and points were awarded for spontaneous corrections. Therefore a score of the number

correct out of 26 possible letter was determined for each child, based on the results of the individually administered test.

Estimated overall intelligence. The combined score of two sub-tests of the *Wechsler Intelligence Scale for children* (WISC-IV) (Wechsler, 2007b) was used as an estimation of intelligence. The WISC-IV is a commonly used assessment of cognitive functioning for children aged 6 to 16. Sub-tests of the WISC-IV have been used frequently to estimate intelligence (IQ) in other recent studies (Hutchison, Beresford, Robinson, & Ross, 2010; Lane, Little, Menzies, Lambert, & Wehby, 2010). The Block Design and Vocabulary sub-tests of the WISC-IV were administered to the participants by a research assistant. Australian norms (Wechsler, 2007) were used in scoring and interpretation of raw scores. The average of a child's scores on the Block Design and Vocabulary sub tests was calculated and used as an estimate of intelligence. Standard scores on each sub-test range from 1 to 19 ($\mu=10$, $\sigma=3$). A number of children ($N = 20$) were not able to participate in the WISC-IV assessments and therefore the results for this assessment were based on the remaining participants ($N = 278$).

Verbal intelligence. The Vocabulary sub-test of the WISC-IV (Wechsler, 2007b) was administered as an estimation of verbal intelligence. This sub-test requires the child to first name three pictures, and, in subsequent items, to provide definitions for words spoken by the examiner. It is considered to be a measure of a child's long-term auditory memory, knowledge of words, verbal concepts and expressive language (Flanagan & Kaufman, 2009). Items 1 through 4 are picture items and items 5 through 56 are verbally administered items, which require the child to provide verbal definitions to words read by the assessor. Children's answers were scored according to the WISC-IV manual. Scores one SD or more below the mean were considered to be in the 'below average' range.

Non-verbal intelligence. An estimation of non-verbal intelligence was assessed using the Block Design sub-test of the WISC-IV (Weschler, 2007b). This sub-test is a measure of visual-perceptual skills and requires the examinee to construct a model from a set of modeled or printed two-dimensional geometric patterns using small red and white blocks, within a preset time period. Children aged 6 began on item 1 and continued until the child made three consecutive zero point responses. Scores one SD or more below the mean were considered to be in the 'below average' range.

Parent interview. The children's parents or caregivers also completed a face-to-face questionnaire with a research assistant at their entry into the study.

Demographic information. Information about the child's address, ethnicity, age and gender was obtained from the parent/caregiver at their entry into the study, in a face-to-face, structured interview with a research assistant. The socio-economic status of the participants was determined according to the New Zealand deprivation score assigned to their home address from the New Zealand census data (Statistics New Zealand, 2010; Salmond, Crampton & Atkinson, 2007; Salmond, Crampton, King & Waldegrave, 2006). In addition, they were asked whether their child (a) had a history of recurrent ear infections and (b) whether their child had received grommets in the past for Otitis Media with Effusion. Finally, they were asked to comment on whether their child had ever had a speech and language difficulty.

Quality of the home learning environment. To measure the child's home learning environment, items from the Learning Stimulation Subscale of the Home Observation for Measurement of the Environment Inventory (HOME) (Bradley, Corwyn, McAdoo, & García Coll, 2003) were administered in the face-to-face interview. These items were in multiple choice format and measured a child's access to activities associated with cognitive

development, and the level of support for learning they received at home. Example items included “How often has any family member taken or arranged to take your child to any type of museum within the past year?” (never, one or several times/ year, or monthly or more), and “Has an adult in your family helped your child learn the alphabet? (Yes/No)” (Bradley et al., 2003). The scores for the HOME Learning Stimulation ranged from 0 to 12, with higher scores indicating higher levels of support.

Teacher report. The children’s new entrant teacher also completed a pen and paper questionnaire at the child’s entry into the study.

Behavioural difficulties. To measure the behavioural difficulties of the participants, teachers who were blind to the study’s objectives, were asked to complete the *Behavior Problem Index* (BPI) (Peterson & Zill, 1986). The BPI is a 28-item, forced choice format behaviour rating scale, for children and adolescents aged 4 to 17 with good reliability and validity, commonly used in international studies (e.g., Christakis & Zimmerman, 2007). The measure lists common behavioural difficulties and respondents indicate whether these are “never,” “sometimes” or “often” true of the child. Items include “(He/She) feels worthless or inferior,” “(He/She) is not liked by other children” and “(He/She) has difficulty getting (his/her) mind off certain thoughts” (Peterson & Zill, 1986). Each teacher was asked to complete the BPI within three weeks of the participating child beginning school. Higher scores indicated greater levels of behaviour difficulties. Children could attain a range of scores on the BPI from 0 to 28.

Vision hearing testing service assessment. The children’s distance vision, middle ear compliance and degree of hearing loss were assessed by Vision Hearing Technicians (VHTs), as part of the National Vision Hearing Screening Programme, a District Health Board initiative. This service carries out population screening of defined cohorts of children,

aged 3 to 11 and aims to identify children with prevalent, undetected ear and eye problems, which may require further assessment and treatment. VHT technicians had attended training courses at the National Audiology Centre (NAC), received professional development and were monitored every two years. The National Vision Screening procedures and standards (New Zealand Vision Hearing Testing Service, 2004) were followed in administration. As per the NZVHT protocols, children's scores were also recorded in their school records by the VHT service staff.

Distance visual acuity. Distance vision was assessed by the Parr Letter Matching Test with confusion bars and logmar increments (Parr, 1981). The child was required to match a letter they saw on the chart with a replica they held. In comparison to the eye charts typically used with adult populations, such as the Snellen chart, where the patient is asked to name letters (Proctor, 2009), the use of confusion bars and pointing to match letters is thought to be the most appropriate, reliable and valid method for testing the distance vision of young children who cannot name letters (Hartman, 2000; McGraw, Winn, Gray & Elliot, 2000; McGraw, Winn & Whittaker, 1995). In addition, the use of optotypes without surround bars is thought to underestimate vision problems (Hartman, 2000). The Parr Letter Matching Test and the similar Sheridan Letter Matching Test have been used to assess distance visual acuity in a number of studies (e.g. Chen et al., 2011; Stewart-Brown et al., 1985; Williams et al., 1988).

As recommended by Hartman, (2000) and the national training protocols, training trials were administered at a close distance at the beginning of the session to ensure the child understood the task (NZVHTS, 2004). For the scored trials, the child was asked to sit on a chair placed 4 metres away from the stimulus card. The technician placed a patch over one of the child's eyes and presented a series of test cards (each test card has one optotype with

confusion bars and otype size decreases with each card). Children were asked to match the otype on each test card with a letter on the card they were holding. The child's performance on each test card was marked as correct or incorrect. Each eye was tested in the same way, with a different sequence of letters.

Visual acuity is described in terms of the clarity or sharpness of a person's vision from a distance of 6 metres, compared to how well an "average" person would see at the same distance. The equivalent of 6/6 vision in the United States literature is 20/20 vision. Therefore, while 6/6 vision is a term used to express that a person has normal visual acuity, a score of 6/9, however, indicates that a child would need to be at 6 metres to read what a typical person could read at 9 metres. A distance vision score of 6/6 in each eye indicates that a child was able to correctly identify three otypes at that level, in that eye, while a score of 6/9 indicates that a child was able to correctly identify three letters at the 6/9 level. VHT technicians also recorded children's results in each eye in their school records, where a "pass" indicated that the vision result was 6/6 or better in that eye, a "retest" if the test was 6/9 vision and a "refer" indicated 6/12 vision.

Middle ear compliance. Tympanometry is a measure of middle ear compliance and was used to determine the presence of OME. Middle ear compliance is the range of movement of the eardrum in response to pressure induced on the tympanic membrane and can be affected by the presence of fluid in the middle ear. (Gutierrez; 2012; Toros & Kalaycik Ertugay, 2011). Tympanometry has been used to indicate OME in a number of studies (e.g. Lous, 1990; McCormick et al., 2006; Walker and Wigglesworth, 2001) and is a standard diagnostic tool for OME.

Tympanometry was carried out in a library or similar quiet room, with a calibrated +200 to 400 dPa range tympanometer (NZVHT, 2004). Tympanograms, which provide a

graphic representation of middle ear compliance were coded into Jerger types (Type A, B or C) by a trained audiologist, blind to the study questions and child demographics.

Flat tympanograms with no sharp peak and little variation in impedance over a wide sweep range are considered to indicate decreased compliance of the tympanic membrane and are coded as Jerger Type B (Toros & Kalaycik Ertugay, 2011). This type of tympanogram can be used to confirm the diagnosis of Otitis Media with Effusion and has an evidence profile of quality B, sensitivity from 83% to 86% and specificity from 63% to 86% (Onusko, 2004; Shishegar, Faramarzi, Esmaili, & Heydari, 2009). Jerger type A is considered to represent normal middle ear compliance and Type C tympanograms are indicative of negative pressure in the middle ear (Rogers et al., 2010). Type C tympanograms do not, however, provide any substantial evidence that a child has middle ear effusion (American Family Physician 2004). In terms of the clinical use of the screening results, children with Jerger type A results were considered to pass, children with Jerger type C were retested, and children with B Jerger type tympanograms were referred to a specialist by the VHT technician following standard protocols.

Degree of hearing loss. Pure tone audiometry testing is used to measure the level and category of hearing loss pitches (Gutierrez, 2012). The assessment involves determining the faintest tones that a person can hear at selected pitches (Gutierrez, 2012). This testing occurred, as normally, in rooms such as school libraries, dental clinics and staff rooms, at the same time as tympanometry assessments, when the rooms were not in use for other purposes. A calibrated screening audiometer (0.5 kHz, 1 kHz, 2 kHz, 4 kHz at 0 to 100 dB presentation range) was used (NZVHT, 2004) and the technician tested each ear individually, at levels of 500, 1000, 2000 and 4000 Hz (NZVHT, 2004). Headphones were placed on the child and they were asked to drop a peg into the container each time they heard a sound. If the child did

not respond, the technician would increase the tone in 5 dB steps until the child responded. Prior to testing, they were asked to practice the task several times to demonstrate their understanding (NZVHT, 2004). If a child obtained an audiometry result of 20 dB at 1000, 2000, 4000 Hz and 30 dB at 500 Hz in both ears (NZVHT, 2004), they received a *õpassõ* score. If a child's initial audiometry levels were marginally elevated, but did not meet or exceed two levels of 45 dBHL or more, they received a *õretestõ* score. Children received a *õreferõ* score if their initial audiometry levels were 45 dBHL or worse on two frequencies (NZVHT, 2004). These results were recorded in the child's school records.

Procedure

Data collection. Upon recruitment into the study, child assessments and parent/caregiver interviews were conducted by a research assistant. The research assistant also contacted the child's teacher and asked her/him to complete the BPI within three weeks of the child's entry into the classroom. After the routine VHT service screen at each of the participating schools, staff provided the researchers with distance vision, tympanometry and audiometry results of each participating child. For some children, data had already been collected and routinely recorded in their school records before the child was recruited into the study. This meant that the researcher instead accessed the child's school records to obtain the child's results, with parent consent.

Twelve months after the child's entry into the study, the researcher contacted the caregivers again and arranged for the cognitive assessment to be administered. The administration of the WISC-IV sub-tests was scheduled twelve months later because the WISC-IV is appropriate for use with children from age 6 upwards only (Weschler, 2007b) and therefore at school entry, the children were too young to be assessed. In the case of

children who had moved away, declined to participate, were too busy or had a critically ill caregiver, cognitive assessments were not able to be completed.

Group assignment. For data analysis, participants were assigned to groups based on their letter name knowledge, vision and OME status.

Children were assigned to one of two groups based on the standardized score equivalent of their letter name knowledge raw score. Children were assigned to the low letter name knowledge group if their score was one standard deviation below the mean or lower. All other children were categorized into the in the not-low letter name knowledge group. This meant that children who knew four or fewer letters were defined as having low letter name knowledge while children who knew five or more letters were defined as having not-low letter name knowledge. This cut-off was also selected because at school, these children would be considered to be in stanine 3 or lower, which means that their scores would be 12 or more months behind their classmates. Stanine 3 is commonly used to define low achievement in New Zealand.

Assignment to vision groups was based on participant's initial distance vision result at school entry. Children were assigned to groups based on their poorest visual acuity score in either eye. Children whose vision data was not obtained (e.g., they were absent on the day of the screening), who wore glasses, had a visual impairment, or obtained a vision score of 6/12 or worse in either eye were excluded from these groups (N=20) because their vision condition was known to affect reading, and excluding them controlled for factors already known to affect reading. Children's scores of 6/9 in both eyes were placed in the 6/9 group. In addition, children found to have 6/9 in one eye and 6/6 in the other were placed in the 6/9 distance vision group. Children who were found to have 6/6 vision in both eyes were assigned to the 6/6 group.

Participants were then assigned to an OME group, independently of their vision status. Results of the hearing screen and parent report were used to categorize scores of the children into OME or not OME groups. Children were included in this analysis if they (a) did not have grommets at school entry and (b) passed their PTA. Children with grommets were excluded from the analyses because they were unable to participate in the tympanometry test. Children were required to pass the PTA test so that types of hearing loss due to causes other than OME would not confound the results. The one exception to the latter criteria was that children who failed the PTA, but had a history of recurrent ear infections were included in the analysis, because their hearing loss was likely to be due to their OME history.

Children with B type tympanograms in one or both ears were assigned to the OME group, as per tympanometry guidelines (American Family Physician, 2004; Hall et al., 2009). Children with current OME were included in the study group due to concern over the reliability of using parent reporting alone, given that OME can go unnoticed (Roberts et al., 2004). In addition, research has shown that the presence of OME at age 5 is associated with a history of hearing problems (Silva et al., 1982). Children with a history of frequent ear infections, as reported by their parent/caregiver were also assigned to the OME group. Children were assigned to the normal hearing group if they had a parent reported history of no frequent ear infections and A or C type tympanogram in both ears at new entry, indicative of no OME.

Children who had been assigned to both a vision group and an OME group were then assigned to another group based on both their tympanometry and distance vision results at school entry. Children with a 6/9 vision in one or both eyes, and/or a B tympanometry result in one or both ears at school entry were assigned to the 6/9 and/or OME group. Children with

6/6 in both eyes and an A or C tympanometry result were assigned to the 6/6 vision and normal hearing group.

Identification of covariates. In order to minimize or control for the effects of factors other than vision and OME on differences in letter name knowledge, covariates associated with poor emergent literacy were selected. The selected covariates were dichotomized into scores, which constituted the presence or absence of risk (Table 1).

Contextual emergent literacy covariates. Ethnicity was selected as a covariate because Māori and Pacific Island children in New Zealand have been shown to enter primary school with fewer emergent literacy skills than their peers (Nicholson, 2003, 2008). This variable was dichotomized into minority (Māori, Pacific Island, Asian and other) and not minority (European). Socio-economic status was selected as a covariate because children of low SES have been found to show delayed letter recognition and phonological sensitivity (Bowey, 1995; Whitehurst & Lonigan, 1998). This covariate was dichotomized into low SES and not-low SES. Children at age 5 have been found to have higher literacy achievement if they have a more stimulating home learning environment (Melhuish et al., 2008). Therefore the children's total scores on the HOME Learning stimulation sub scale (Bradley et al., 2003) were dichotomized into low home learning (one SD or more below the mean) and not-low HOME help (all other scores) to represent this covariate. In addition, as children who are read to three or more times per week have been found to have better reading skills at school entry (Nord et al., 2000), an item from the HOME Learning Stimulation Scale, which asked respondents to indicate how often an adult read to their child, was used to obtain this information was included as a potential covariate. This covariate of shared reading was dichotomized into less than three times a week and three times or more a week. Children who receive help in learning letters have also been found to have better reading skills at

school entry (Nord et al., 2000). Therefore, another item from the HOME Inventory (Bradley et al., 2003), which asks whether or not someone in the child's family had taught them letters of the alphabet, was used to reflect this covariate.

Individual child emergent literacy covariates. Cognitive ability has also been shown to be an important factor in the development of school readiness reading skills (Evans et al., 2006) and therefore intelligence was selected as a covariate. The combined score of the WISC-IV sub-tests; Vocabulary and Block Design (Weschler, 2007b), was used as an estimate of intelligence. These scores were dichotomized as low (one standard deviation below the mean or lower) and not-low (all other scores). The parent report of child's history of speech and language difficulties was chosen as a covariate because children with such a history have been found to perform more poorly than their peers and matched counterparts at rhyming and letter naming tasks at school entry (Raitano et al., 2004). This variable was dichotomized into speech and language problem and no speech and language problem. Behavioural difficulties at school are related to lower levels of achievement in kindergartners and first graders (Normandeau & Guay, 1998). Therefore behaviour problem scores, as indicated by the teacher's report on the BPI were included as a covariate. The children's scores were dichotomized into "behaviour problem" (one SD and above the mean) and "no behaviour problem" (all other scores). This meant a score of 8 on the BPI or above was considered to reflect a behaviour problem.

Table 1
Variables, codes and dichotomization used in the data analysis

Variable	Dichotomization	Label assigned for covariate
Low socio economic status	Low SES vs. Not-low SES	low SES
Clinically high score on the BPI	Scores \times 1SD above the mean vs. other scores	behaviour problem
6/9 distance vision	6/9 vision vs. 6/6 vision	6/9 vision
OME group	OME group vs. non OME	OME
Low score on the HOME scale	Scores \ddot{O} 1 SD below the mean vs. other scores	low home learning
Alphabet help	Help received in learning letters vs. no help received in learning letters	alphabet help
Male gender	boy v. girl	gender
Minority Ethnicity	Minority vs. European	ethnicity
Speech and language problem	Speech and language problem history vs. no speech and language problem history	speech language problem
Shared reading	< 3 times per week shared reading vs. \times 3 times per week	shared reading
Low estimated IQ	WISC-IV combined scores \ddot{O} 1 SD below the mean	low IQ

Data analysis.

SPSS software (version 19.0 SPSS) was used for all analyses. For the first step of the analysis, children were classified into groups by assigning values to their new entrant vision and hearing results, as described above. Logistic regression model testing was then performed to determine whether 6/9 vision, OME or minor sensory problems (6/9 distance vision and/or B tympanometry result) identified at entrance to school could predict low letter name knowledge. Covariates were tested individually in logistic regression model testing, using

low letter name knowledge as the dependent variable. Logistic regression was used in these analyses as the objective of this study was to explain low letter name knowledge. This was an unconditional logistic regression. A criterion of ($p \leq 0.1$) was used for selection of a covariate into model testing, and a criterion of ($p \leq 0.05$) was used for retaining variables in the model. The models were tested using block entry of the variables, in order of beta values from single model testing. A constant was included in all model testing.

Chapter 4

Results

The planned data analyses were completed. The characteristics of the participants and the results for the cohort's letter knowledge are presented first, followed by analyses of the effects of 6/9 vision and OME status on emergent letter name knowledge. A logistic regression model which included the variables of 6/9 distance vision, OME status and covariates of emergent literacy is then presented. Following this, a logistic regression analysis of the relationship between the presence of one or both of these sensory problems at school entry and letter name knowledge is shown. Finally, an analysis of the relationship between cumulative emergent literacy risk factors and letter name knowledge is presented.

Characteristics of the Participants

The children were English speaking, and had a parent or caregiver who was also English speaking. The participants had a mean age of 60.19 months ($SD = 0.95$), and belonged to various ethnic groups and socio demographic levels (Table 2). The mean IQ scores of the participants were within the average range.

Table 2
Participant characteristics

Descriptor	Mean (SD) / N (%)
Age in months at commencement of the study (SD)	60.19 (0.95)
Gender	
Girls N (%)	153 (51.3)
Boys N (%)	145 (48.7)
Ethnicity	
New Zealand European N (%)	223 (74.8)
M ori N (%)	47 (15.8)
Pacific Island N (%)	14 (4.7)
Asian N (%)	9 (3.0)
Other N (%)	5 (1.7)
Socio economic status	
High N (%)	64 (21.5)
Mid N (%)	122 (40.9)
Low N (%)	112 (37.6)
Estimated WISC-IV combined sub-test Mean (SD)	9.8 (2.52)
Vocabulary sub-test Mean (SD)	9.7 (2.20)
Block Design sub-test Mean (SD)	10.0 (2.91)
Speech and language problem N (%)	55 (18.6)
HOME learning environment Mean (SD)	9.6 (1.69)
Read to three or more times per week N (%)	257 (86.2)
Received help in alphabet learning N (%)	287 (96.6)
Behaviour Problem Index Mean (SD)	3.29 (4.28)

Children's Letter Name Knowledge at School Entry

The mean letter name knowledge score for the total cohort (N=298) was 13.26 (SD=8.72).

Children were assigned to groups based on their letter name knowledge. Of the total cohort, 23% were assigned to the low letter name knowledge group and 77% were assigned to the not-low letter name knowledge group. The letter name knowledge scores of the cohort are displayed in Figure 3.

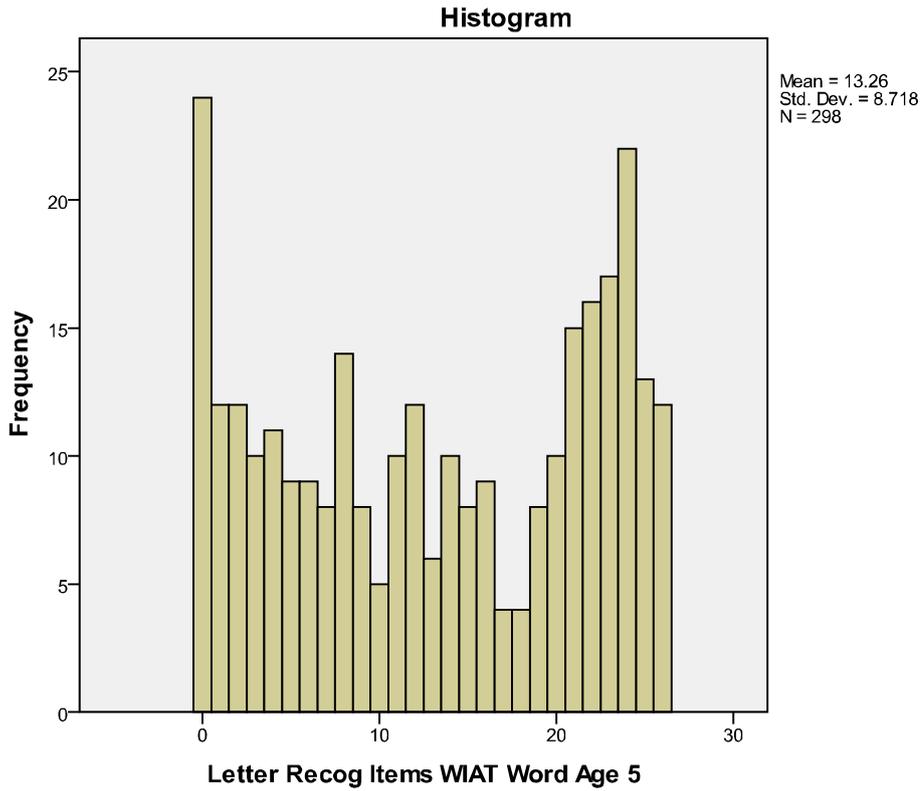


Figure 3. Number of children (N=298) at each raw score (0-26) on the letter-knowledge test.

Characteristics of Children’s Vision at School Entry

Of the total cohort, 61.4% had 6/6 vision results at school entry, while 28.5% had 6/9 in both eyes (Table 3). Some children had 6/6 in one eye and 6/9 in the other (3.4%). The remaining children had 6/12 in one or both eyes (2.0%), wore prescription glasses (1.0%) or had another type of visual impairment (1.0%), or vision data was not available (2.7%).

Table 3
Vision characteristics of the cohort

Screening outcome	(N)	%
6/6 in both eyes	183	(61.4%)
6/9 in one eye, 6/6 in the other	10	(3.4%)
6/9 in both eyes	85	(28.5%)
6/12 in one or both eyes	6	(2.0%)
Prescription Glasses	3	(1.0%)
Other visual impairment	3	(1.0%)
Vision data was not obtained	8	(2.7%)

The Relationship between 6/9 Vision and Letter Name Knowledge

Children were assigned to groups based on their new entrant vision results. Of the 298 children, 61.4% were assigned to the 6/6 vision group, 31.9% were assigned to the 6/9 distance vision group and 6.7% were excluded. Of the children included in these analyses (N = 278), 22.7% of the children were in the low letter name knowledge group.

For the first step of the analysis, the differences between the 6/6 group and the 6/9 group on factors known to be associated with emergent literacy were tested using t-tests or chi-squares (Table 4). Children in the 6/9 group were significantly more likely to be of low SES ($p \leq 0.05$). A higher proportion of children in the 6/6 group had shared reading at home more than 3 times per week (89.1%) as compared to the 6/9 group (80%) ($p < 0.05$) and a higher proportion of children in the 6/9 vision group had low home learning (29.5%) than the 6/6 vision group (19.7%). Children in the 6/9 group were more likely to have low Block Design scores ($p \leq 0.05$) than the 6/6 group. The Vocabulary and combined WISC IV sub-

test mean scores of the 6/9 group were also found to be significantly lower than children in the 6/6 group ($p \leq 0.05$). Other group differences did not reach significance.

Table 4
The relationship between 6/9 vision and emergent literacy covariates

Descriptor	Type	6/6 vision (N= 183)	6/9 in one/both eyes (N= 95)	Chi square/ t test	<i>p</i>
Age	Mean (SD)	60.2 (0.97)	60.12 (0.92)	t = -.692	0.490
Gender	Boys % (N)	47.5 (87)	48.4 (46)	$\chi^2 = 0.019$	0.889
	Girls % (N)	52.5 (96)	51.6 (49)		
SES	Low % (N)	31.7 (58)	9.5 (49)	$\chi^2 = 14.79$	0.001**
	Mid % (N)	42.6 (78)	38.9 (37)		
	High % (N)	25.7 (47)	51.6 (9)		
Home learning	Mean (SD)	9.75 (1.52)	9.51 (1.83)	t = 1.205	0.229
Environment	Low % (N)	19.7 (36)	29.5 (28)	$\chi^2 = 3.390$	0.066
Reading at Home	$\times 3$ /week % (N)	89.1 (163)	80.0 (76)	$\chi^2 = 4.266$	0.039*
Alphabet help	Yes % (N)	97.8 (179)	95.8 (91)	$\chi^2 = 0.902$	0.342
WISC-IV combined (N = 278)	Mean (SD)	10.1 (2.09)	9.46 (2.12)	t = 2.463	0.014*
	Low % (N)	12.3 (21)	25.0 (23)	$\chi^2 = 6.947$	0.008*
Vocabulary sub-test (N= 278)	Mean (SD)	9.97 (2.53)	9.22 (2.07)	t = 2.450	0.015*
	Low % (N)	12.3 (21)	19.6 (18)	$\chi^2 = 2.513$	0.113
Block Design sub test (N = 278)	Mean (SD)	10.3 (2.83)	9.71 (2.98)	t = -1.571	0.117
	Low % (N)	15.2 (26)	27.2 (25)	$\chi^2 = 5.482$	0.019*
Behaviour Problem	Mean (SD)	3.16 (3.88)	3.24 (4.27)	t = 0.149	0.881
	Behaviour problem% (N)	12.6 (23)	24.2 (13)	$\chi^2 = 0.069$	0.793

Descriptor	Type	6/6 vision (N= 183)	6/9 in one/both eyes (N= 95)	Chi square/ t test	<i>p</i>
Speech Language problem	Yes % (N)	16.4 (30)	22.3 (21)	$\chi^2=1.462$	0.227

* $p \leq 0.05$, **2 x 2 Low SES vs. not-low SES ($\chi^2=10.445$, $p=0.001$)

The second step of the analysis was to determine the relationship between 6/9 distance vision and letter name knowledge (Table 5). A higher proportion of children in the 6/9 vision group had low letter knowledge than in the 6/6 group ($\chi^2 = 6.547$, $p=0.011$), with an odds ratio of 2.098, (CI_{0.95}=1.182 - 3.724). Children with 6/9 distance vision were also found to have a significantly lower letter name knowledge mean score than children with 6/6 distance vision ($t = -3.479$, $p = 0.001$).

Table 5
The relationship between 6/9 vision and letter name knowledge

Descriptor	6/9	6/6	Analysis
All children			
N	95	183	$t = -3.479^{**}$
Mean Letter Name (SD)	10.84 (8.4)	14.56 (8.5)	$\chi^2 = 6.547^*$
Low Letter Name Group (%)	30 (31.6%)	33 (18.0%)	
Excluding low IQ			
N	69	150	$t = -3.158^{**}$
Mean letter name score (SD)	11.62 (8.5)	15.4 (8.2)	$\chi^2 = 6.975^{**}$
Low Letter Name Group (%)	20 (28.9%)	21 (14.0%)	

* $p \leq 0.05$, ** $p \leq 0.01$

The third step controlled for the effects of low intelligence. Children with low IQ were excluded. This was necessary, as the children in the 6/9 group were significantly more likely

to have a low estimated IQ ($p \leq 0.05$) and children with low intelligence are more likely to have low school readiness (Scarborough, 1988). There were 219 children in the retained group. Of these children, 68.5% had 6/6 distance vision and 31.5% had 6/9 distance vision, 18.7% had low letter name knowledge 81.3% were in the not-low letter knowledge group. Even after the exclusion of children with low IQ, children with 6/9 distance vision were significantly more likely to have low letter name knowledge than children with 6/6 distance vision ($p = 0.008$), with an odds ratio of 2.507 ($CI_{0.95} = 1.251- 5.024$). The 6/9 distance vision group also had a significantly lower mean letter knowledge score than the 6/6 group ($p = 0.002$).

The Relationship between 6/9 Vision and Letter Name Knowledge, Controlling for Covariates of Emergent Literacy

The fifth step in the analysis was to analyze the relationship between covariates of emergent literacy and low letter name knowledge; low SES, low home learning, minority ethnic group, male gender, behaviour problem, alphabet help at home, shared reading, and speech and language difficulties. The speech and language difficulty variable was not retained as a covariate in single model testing, as subsequent to the exclusion of children with low estimated intelligence scores, there were only 4 children with a speech and language difficulty. The overall low home learning variable was selected for model testing instead of the alphabet help and shared reading variables, as these three variables were all derived from the HOME scale (Bradley, 2003). The estimated IQ covariate was not able to be included as a covariate in model testing, due to the very strong correlations between the measures of IQ (WISC IV) and letter name knowledge (WIAT II) used in this study. Research has shown that performance on each of these psychometric tests is highly, positively and significantly related to performance on the other, with correlations of 0.75 to 0.85 (Konold & Canivez, 2010). In

addition, intelligence was partially controlled for by the exclusion of children with low IQ. Therefore the covariates retained for single model testing were low SES, behaviour problems, low home learning, minority ethnicity and male gender.

Individual chi square analyses were performed to determine relationships between these variables and low letter name knowledge. Low SES ($\chi^2 = 9.228, p = 0.002$) and low home learning ($\chi^2 = 6.732, p = 0.009$) were found to be significantly associated with low letter name knowledge at school entry. The variable of behaviour problem was found to approach significance ($\chi^2 = 3.801, p = .051$). The variables of gender ($\chi^2 = 1.891, p = 0.169$) and minority ethnicity ($\chi^2 = 1.010, p = .315$) were not significantly associated with low letter name knowledge.

For the sixth step, single model logistic regression analyses were performed independently with each covariate to determine how much of the variance in letter name knowledge could be independently explained by each covariate (Table 6). A constant was included in all model testing. Covariates were excluded from further model testing if they did not meet the criteria for significance ($p \leq 0.10$). Four variables (low SES, low home learning, 6/9 vision and behaviour problem) were significantly associated with low letter name knowledge ($p \leq .10$). The covariate of behaviour problem was retained in the model because of its strength as a covariate in other studies, and because it missed the criteria by .01. Two variables, minority ethnicity and male gender, were removed from further model testing as they did not reach significance. Prior to full model testing, the remaining covariates were then ranked according to their beta values. Covariates with higher beta values were entered into the model first.

Table 6

The relationship between 6/9 vision, emergent literacy covariates and letter name knowledge

Variable	Dichotomization		<i>p</i>
Low SES	low vs. not-low	1.050	0.003
Low home learning	scores ≥ 1 sd below the mean vs. other scores	0.980	0.011
6/9 vision	6/9 vision vs. 6/6 vision	0.919	0.010
Behaviour problem	scores $\times 1$ sd above the mean vs. other scores	0.856	0.056
Male gender	boy v. girl	0.480	0.171
Minority ethnicity	Minority vs. European	0.389	0.317

For the last step of the analyses, a series of logistic regression models were performed (Table 7) in order to determine what proportion of the variance in low letter name knowledge could be explained by 6/9 distance vision, and what proportion was explained by other variables. Four models were tested and the final model consisted of low SES and 6/9 distance vision (Model 4). Model 4 significantly predicted low letter name knowledge, with an r^2 value of 0.056 ($\chi^2 = 12.652$, $p < 0.01$). The covariate of 6/9 distance vision significantly explained low letter name knowledge (OR = 2.069, $p = 0.050$). Low SES also significantly explained low letter name knowledge (OR = 2.45, $p < 0.05$).

Table 7

The relationship between 6/9 vision and letter name knowledge, controlling for emergent literacy covariates

Covariates in the Model	Odds Ratio for the covariate	Lower 95% CI for the covariate	Upper 95% CI for the covariate	<i>p</i>
Model 1				
Low SES	2.858	1.428	5.720	0.003
Model 2				
Low SES	2.446	1.91	5.025	0.015
Low home learning	2.069	0.936	4.575	0.072
Model 3				
Low SES	2.450	1.198	5.009	0.014
6/9 distance vision	2.069	.999	4.227	0.050
Model 4				
Low SES	2.393	1.164	4.920	0.018
6/9 distance vision	2.101	1.015	4.351	0.046
Behaviour problem	2.315	.927	5.779	0.72
Model 5				
Low SES	2.450	1.198	5.009	0.014
6/9 distance vision	2.069	.999	4.227	0.050

Characteristics of Children's Hearing at School Entry

The new entrant results showed that 94.3% children passed the pure tone audiometry initially or on referral (Table 8). Of the referred children, one child received a diagnosis of mild hearing loss, four children passed on retest by a specialist, ten were under specialist care and six referral results were unknown at the conclusion of the study.

Table 8
Hearing characteristics of the cohort

Screening Outcome	N	(%)
Pure Tone Audiometry (N = 298)		
Pass PTA	281	(94.3%)
Fail PTA	17	(5.7%)
Fail PTA (N=17)		
Mild hearing loss diagnosis	1	(5.8%)
Under care	10	(58.8%)
Outcome unknown	6	(35.3%)
Tympanometry (N=281)		
A/C in both ears	256	(91.1%)
B one/both ears	21	(7.5%)
Grommets in one or both ears	4	(1.4%)
Parent-reported History (N = 298)		
No frequent ear infections	192	(64.4%)
Recurrent ear infections	106	(35.6%)
Recurrent Ear Infections (N = 106)		
Past grommets	42	(39.6%)
No grommets	64	(60.4%)

Of the children who passed the PTA initially or on referral, 91.1 % passed the tympanometry test (A or C in both ears), 7.5% obtained a B result in one or both ears, and 1.4% of children were unable to be tested as they had grommets. Of the total cohort, 35.6% of children had frequent ear infections during their developmental years, as reported by parents, and about 1/3 of these children had frequent infections from age 4. Of the children with a history of

frequent ear infections, 39.6% had been treated with grommets in the past, while 60.4% had not received grommets in the past.

The Relationship between OME Status and Emergent Letter Name Knowledge

For the first step of the analysis, children were assigned to groups based on their OME result and their parent reported history of ear infections. Twenty-one children had a B type tympanogram in one or both ears and 90 additional children had parent reported histories of OME. Therefore the OME group consisted of 111 children (37.2%). The normal hearing group consisted of 175 children. A total of 12 children were excluded from these analyses. Of the children included in this analysis (N=286), 23.1% of the children were in the low letter knowledge group.

The second step of the analysis was to examine the differences between the OME and normal hearing groups on contextual factors known to affect the development of emergent literacy skills, through t-tests and chi square analyses (Table 9). Significantly more children in the OME group were of minority ethnic groups ($p = .037$) and of low SES ($p = 0.008$). There was also a higher proportion of children in the OME group with a behaviour problem (17%) than in the normal hearing group (10.3%), but this difference did not reach significance. No other contextual variable reached significance.

Table 9

The relationship between OME status and emergent literacy covariates

Descriptor	Type	OME group (N=111)	Normal hearing group (N=175)	Chi square/ t test	<i>p</i>
Age	Mean (SD)	60.19 (0.86)	60.21 (1.01)	$t = -.179$	.858
Gender	Boys % (N)	50.50 (56)	45.70 (80)	$\chi^2 = .611$	.434
	Girls % (N)	49.50 (55)	54.30 (95)		
SES	Low % (N)	36.90 (41)	36.60 (64)	$\chi^2 = .408$	.815**
	Mid % (N)	43.24 (48)	40.60 (71)		
	High % (N)	19.81 (22)	22.90 (40)		
Ethnicity	European % (N)	68.47 (76)	79.43 (139)	$\chi^2 = 4.372$	.037*
	Minority % (N)	31.53 (35)	20.57 (36)		
Home	Mean (SD)	9.55 (1.61)	9.65 (1.71)	$t = -.474$	.636
Learning	Low % (N)	25.20 (28)	22.86 (40)	$\chi^2 = .210$	.647
Stimulation					
Shared	× 3 per week %	82.90 (92)	89.14 (156)	$\chi^2 = 2.310$	.129
Reading	(N)				
	< 3 per week %	17.10 (19)	10.86 (19)		
	(N)				
Alphabet	Yes % (N)	98.20 (109)	4.00 (7)	$\chi^2 = 1.093$	.296
Help					
WISC IV	Mean (SD)	9.75 (2.43)	9.99 (2.02)	$t = -.882$	.379
combined	Low % (N)	12.50 (13)	7.90 (13)	$\chi^2 = 1.479$	.224
score					
WISC IV	Mean (SD)	9.58 (2.60)	9.77 (2.49)	$t = -.615$	.539
Vocabulary	Low % (N)	21.15 (22)	12.27 (20)	$\chi^2 = 3.780$	.052
sub test					
WISC IV	Mean (SD)	9.91 (3.13)	10.20 (2.76)	$t = -.793$	.429
Block Design					
sub test	Low % (N)	21.15 (22)	18.40 (30)	$\chi^2 = .306$	.580

Descriptor	Type	OME group (N=111)	Normal hearing group (N=175)	Chi square/ t test	<i>p</i>
Behavior	Mean (SD)	3.65 (4.24)	3.01 (4.27)	t = 1.234	.218
Problem Index	Behaviour problem % (N)	17.10 (19)	10.30 (18)	2.814	.093
Speech/ language problem	Yes % (N)	17.43 (19)	18.30 (32)	.033	.855

* $p \leq 0.05$

**2 x 2 chi square low SES vs. not-low SES, $\chi^2=11.871$, ($p=0.008$).

The third step of the analysis was to determine the relationship between OME and letter name knowledge (Table 10). A significantly higher proportion of children in the OME group had low letter knowledge than in the normal hearing group ($p = 0.03$). The odds ratio for having low letter knowledge if a child was in the OME group was 1.821 ($CI_{0.95} = 1.044 - 3.174$) ($p < 0.05$).

Table 10

The relationship between OME status and letter name knowledge

Descriptor	Groups		Analysis
	OME (N=111)	Normal Hearing (N=175)	
Percentage of children in each group with low letter knowledge	27.03% (33)	18.86% (33)	$\chi^2 = 4.523^*$
Mean Letter Knowledge score (SD)	12.36 (9.19)	13.91 (8.39)	t = -1.470 <i>n.s</i>

* $p \leq 0.05$

The Relationship between OME Status and Letter Name Knowledge, Controlling for Covariates of Emergent Literacy

For the fourth step of the analysis, the relationship between the covariates and letter knowledge was analyzed. Children with low IQ were retained in the analysis, as there was not a relationship between estimated IQ and OME status ($\chi^2=1.479$, $p = .224$). Individual chi square analyses of the relationship between the covariates (low SES, behaviour problems, low home learning, male gender, speech and language problems and minority ethnicity) and low letter name knowledge were performed. The covariates of low SES ($\chi^2=13.823$, $p < 0.001$), behaviour problem ($\chi^2= 9.736$, $p = 0.002$) and low home learning ($\chi^2 = 11.548$, $p =0.001$) were significantly associated with low letter name knowledge.

For the fifth step, single model logistic regression testing was performed independently for each covariate to determine their relationship with low letter name knowledge (Table 11). Covariates were excluded from further model testing if they did not meet the criteria for significance ($p \leq .10$). Four variables (low SES, low home learning, OME and behaviour problem) were significantly associated with low letter name knowledge ($p \leq .10$). The variables of minority ethnicity, speech and language problem and male gender did not reach significance and were therefore removed from further model testing.

Table 11

The relationship between OME status, emergent literacy covariates and low letter name knowledge

Category	Dichotomization		<i>p</i>
Behaviour problem	scores \times 1 sd above the mean vs. other scores	1.109	0.003
Low SES	low SES vs. not-low SES	1.048	<0.001
Low home learning	scores \bar{O} 1 sd below the mean vs. other scores	.636	0.001
OME	past or current OME vs. No OME	.599	.035
Male gender	boy v. girl	.365	.196
Minority Ethnicity	Minority vs. Non-minority	.365	.242
Speech and language difficulty	speech language problem vs. no speech and language problem	0.044	.904

The sixth step was the performance of full logistic regression model tests (Table 12). The models were tested using block entry of the variables, in order of the highest to lowest beta values from single model testing. A constant was included in all model testing and a criterion of ($p \leq .05$) was used as the significance level for retaining variables in the model.

Table 12

The relationship between OME status and letter name knowledge, controlling for emergent literacy covariates

Covariates in the Model	Odds Ratio for the covariate	Lower 95% CI	Upper 95% CI	<i>p</i>
Model 1				
Behaviour problem	3.032	1.475	6.233	0.003
Model 2				
Behaviour problem	2.975	1.415	6.256	0.004
Low SES	2.821	1.589	5.006	<0.001
Model 3				
Behaviour problem	2.605	1.220	5.562	0.013
Low SES	2.519	1.401	4.528	0.002
Low home learning	2.042	1.086	3.842	0.027
Model 4				
Behaviour problem	2.462	1.146	5.290	0.021
Low SES	2.571	1.421	4.649	0.002
Low home learning	2.026	1.069	3.840	0.030
OME status	1.759	.977	3.165	0.060

The model which explained the most variance in low letter name knowledge at school entry (9.8 %) and significantly predicted low letter name knowledge ($\chi^2=29.643, p < 0.001$) consisted of four variables, behaviour problem, low SES, low home learning and OME. The OME variable was found to predict low letter name knowledge, with an odds ratio of 1.778, but did not reach significance ($p = 0.06$). In this model, the variables of low SES, low home learning and behaviour problem were more strongly associated with low letter name knowledge than OME status.

The covariate of behaviour problem was removed from the next model testing because chronic OME can be associated with increased behavioural difficulties (Roberts, Burchinal & Campbell, 1994). Model 3 (Table 13), which consisted of low SES, low home learning and OME, significantly predicted 8.2% of the variance in letter name knowledge ($\chi^2=24.522, p < 0.001$). OME was found to be a significant predictor of low letter name

knowledge, with an odds ratio of 1.846 (CI0.95 =1.034 ó 3.297, p =0.038) without controlling for behaviour problems. Both low SES and low home learning were also found to be significantly associated with low letter name knowledge (p<0.05) in this model.

Table 13

The relationship between OME status and letter name knowledge, controlling for contextual emergent literacy covariates

Covariates in the Model	OR for the covariate	Lower 95% CI for the covariate	Upper 95% CI for the covariate	P for the covariate
Model 1				
Low SES	2.852	1.623	5.013	<0.001
Model 2				
Low SES	2.486	1.393	4.435	0.002
Low home learning	2.300	1.241	4.265	0.008
Model 3				
Low home learning	2.277	1.219	4.254	0.010
Low SES	2.517	1.401	4.519	0.002
OME status	1.846	1.034	3.297	0.038

The Relationship Between 6/9 Distance Vision, OME Status and Letter Name

Knowledge, Controlling for Emergent Literacy Covariates

OME status and 6/9 vision had been analyzed in separate models. In this step, logistic model testing was conducted with the inclusion of both of these variables in addition to the covariates. The scores of children who had been included in the previous groups (OME v. normal hearing; 6/9 vision v. 6/6 vision) were included in this analysis (N=267). Of these, 11.24% had both OME status and 6/9 vision, 28.10% had OME with 6/6 vision, and 22.47% had normal hearing and 6/9 vision, with 38.19% in the group without either mild sensory condition. In the analyzed group, 22.5% had low letter knowledge and 77.5% did not.

For the first step of the analysis, single model logistic regression testing was performed independently for OME status, 6/9 distance vision, and covariates found to

significantly predict letter name knowledge in the previous models (Table 14). The covariates tested were 6/9 distance vision, OME status, low SES, low home learning and behaviour problems. All of the covariates met the inclusion criterion of ($p < 0.1$) and were therefore retained as variables for the full model testing.

Table 14
The relationship between 6/9 vision, OME status, emergent literacy covariates and letter name knowledge

Category	Dichotomization		<i>p</i>
Behaviour problem	scores \times 1 sd above the mean vs. other scores	1.193	0.002
Low home learning	scores \ddot{O} 1 sd below the mean vs. other scores	1.049	0.001
Low SES	low SES vs. not-low SES	1.027	0.001
6/9 vision	6/9 vs. 6/6	0.806	0.007
OME	past or current OME vs. No OME	0.653	0.028

For the second step, logistic regression model testing was performed (Table 15). Covariates were entered into the models in order of their beta values from single model testing. The final model, which explained the most variance in letter name knowledge (12.2%) consisted of behaviour problem, low SES, low home learning, 6/9 distance vision and OME. This model was a significant predictor of letter name knowledge ($\chi^2 = 34.624, p < 0.001$). Both OME status and 6/9 distance vision were found to be highly significantly associated with low letter name knowledge ($p \leq 0.05$) in this model. OME status had an odds ratio of 2.141 ($CI_{0.95} = 1.142 - 4.016$) and 6/9 distance vision had an odds ratio of 2.110 ($CI_{0.95} = 1.114 - 3.997$). All of the other included covariates were also found to explain unique variance in letter name knowledge.

Table 15

The relationship between 6/9 vision, OME status and letter name knowledge, controlling for emergent literacy covariates

Covariates in the Model	Odds Ratio for the covariate	Lower 95% CI for the covariate	Upper 95% CI for the covariate	P for the covariate
Model 1				
Behaviour problem	3.298	1.556	6.990	0.002
Model 2				
Behaviour problem	2.880	1.330	6.234	0.007
Low home learning	2.577	1.351	4.915	0.004
Model 3				
Behaviour problem	2.938	1.339	6.445	0.007
Low home learning	2.067	1.058	4.040	0.034
Low SES	2.389	1.286	4.440	0.006
Model 4				
Behaviour problem	3.012	1.368	6.633	0.006
Low home learning	2.037	1.037	4.000	0.039
Low SES	2.136	1.134	4.022	0.019
6/9 vision	1.928	1.032	3.602	0.040
Model 5				
Behaviour problem	2.928	1.320	6.495	0.008
Low home learning	2.035	1.023	4.049	0.043
Low SES	2.196	1.320	6.495	0.016
6/9 vision	2.110	1.114	3.997	0.022
OME status	2.141	1.142	4.016	0.018

The relationship between 6/9 distance vision, OME status and letter name knowledge, controlling for covariates of emergent literacy, including low IQ. Logistic regression model testing was then performed, with low IQ as a covariate, as well as behaviour problem, low SES, low home learning, 6/9 vision and OME, to determine the relationship between these variables and emergent literacy. The covariate of low IQ was not included as a covariate in the previous analyses due to the high correlations between the WIAT II and the WISC IV. However, cognitive development has been shown to be associated with emergent literacy (Scarborough, 1988) and a single model test showed that low IQ was a significant predictor of low letter knowledge in the cohort ($\beta = 1.182, p =$

0.002). In addition, both OME and vision problems have been found to be associated with cognitive difficulties in the literature (Atkinson et al, 2002; Lindsay, Tomazic, Whitman & Accardo, 1999; Paradise et al, 2000; Roberts & Wallace, 1997;) and a higher proportion of children in the 6/9 vision group had low estimated IQ scores ($\chi^2=5.553, p = 0.019$).

When low IQ was added as a covariate (Table 16), the low home variable became insignificant ($p = 0.075$) and was removed from the model. The 6/9 vision covariate was retained in the model as it approached significance as a predictor of low letter knowledge ($p = 0.053$). The final model consisted of low IQ, behaviour problem, low SES, 6/9 vision and OME, and was found to significantly predict 13% of the variance in letter name knowledge at school entry ($\chi^2 = 35.134, p < 0.001$). The OME variable was found to be a significant predictor of low letter knowledge ($p < 0.05$) and the variable of 6/9 vision approached significance ($p = 0.052$).

Table 16

The relationship between 6/9 vision, OME status and letter name knowledge, controlling for emergent literacy covariates, including low IQ

Covariates in the Model	Odds Ratio for the covariate	Lower 95% CI for the covariate	Upper 95% CI for the covariate	<i>p</i> for the covariate
Model 6				
Behaviour problem	2.720	1.179	6.277	0.019
Low IQ	2.847	1.289	6.290	0.010
Low home learning	1.926	0.936	3.961	0.075
Low SES	2.239	1.152	4.353	0.017
OME status	1.969	1.027	3.773	0.041
6/9 vision	1.925	0.991	3.736	0.053
Model 7				
Behaviour problem	3.016	1.325	6.864	0.009
Low IQ	3.013	1.379	6.585	0.006
Low SES	2.555	1.341	4.869	0.004
OME status	1.934	1.015	3.685	0.045
6/9 vision	1.923	.995	3.717	0.052

The Relationship between 6/9 and/or OME Group Status at School Entry and Letter Name Knowledge

An analysis was then performed to determine whether a group of children with 6/9 distance vision and/or B tympanometry results at school entry had lower letter name knowledge than children with 6/6 vision and normal hearing at school entry. The first step of the analysis was to assign children to groups based on both their tympanometry and vision results. Of the 267 children, 37.8% were assigned to the 6/9 and/or OME group and 62.2% were assigned to the 6/6 and normal hearing group.

The second step of the analysis was to examine the differences between the 6/9 and/or OME group and the 6/6 and normal hearing groups on emergent literacy covariates, through t-tests and chi square analyses (Table 17). In the 6/9 and/or OME group, there was a significantly higher proportion of children of low SES (47.52%) than in the 6/6 and normal

hearing group (31.33%). Children in the 6/9 and/or OME group also had significantly lower estimated IQs and significantly lower Vocabulary sub-test scores ($p < 0.05$). In addition, a significantly higher proportion of children in the 6/9 and/or OME group were categorized as having low WISC IV combined scores (22.45%) than in the 6/6 and normal hearing group (10.97%). A higher proportion of children in the 6/9 and/or OME group were categorized as having low vocabulary scores (20.41%) than the 6/6 and normal hearing group (10.33%). Other group differences did not reach significance.

Table 17
The relationship between the 6/9 vision and/or OME group status and emergent literacy covariates

Descriptor	Type	6/9 and/or OME group (N = 101)	6/6 and normal hearing group (N = 166)	Chi square/ t test	<i>p</i>
Age	Mean (SD)	60.15 (0.89)	60.21 (1.00)	t = -.591	0.111
Gender	Boys % (N)	45.55 (46)	47.59 (79)	$\chi^2 = 0.106$	0.745
	Girls % (N)	54.45 (55)	42.41 (87)		
SES	Low % (N)	47.52 (48)	31.33 (52)	$\chi^2 = 11.84$	0.003*
	Mid % (N)	41.58 (42)	42.17 (70)		
	High % (N)	10.89 (11)	31.11 (52)		
Ethnicity	European % (N)	71.28 (72)	78.31 (130)	$\chi^2 = 1.683$	0.195
	Minority % (N)	28.71 (29)	21.68 (36)		
Home learning	Mean (SD)	9.63 (1.75)	9.72 (1.52)	t = -.439	0.661
	Low % (N)	26.73 (27)	19.87 (33)	$\chi^2 = 1.693$	0.193
Shared reading	× 3 per week % (N)	82.18 (83)	10.84 (18)	$\chi^2 = 2.62$	0.105
	< 3 per week % (N)	17.82 (18)	89.16 (148)		
Alphabet Help	Yes % (N)	97.03 (98)	96.58 (161)	$\chi^2 = 0.073$	0.787
WISC IV combined (N = 278)	Mean (SD)	9.60 (2.13)	10.19 (2.07)	t = -2.188	0.030*
	Low % (N)	22.45 (22)	10.97 (17)	$\chi^2 = 6.070$	0.014*
WISC IV Vocabulary	Mean (SD)	9.28 (2.20)	10.04 (2.50)	t = -2.473	0.014*
	Low % (N)	20.41 (20)	10.33 (16)	$\chi^2 = 5.004$	0.025*
WISC IV Block Design	Mean (SD)	9.93 (2.88)	10.34 (2.86)	t = -1.134	0.258
	Low % (N)	23.47 (23)	14.80 (23)	$\chi^2 = 3.006$	0.083
Behaviour problem	Mean (SD)	3.25 (3.82)	3.10 (4.27)	t = .280	0.780
	Behaviour Problem % (N)	13.86 (14)	12.05 (20)	$\chi^2 = .186$	0.666

Descriptor	Type	6/9 and/or OME group (N = 101)	6/6 and normal hearing group (N = 166)	Chi square/ t test	<i>p</i>
Speech/ language problem	Yes % (N)	18.81 (19)	16.87 (28)	$\chi^2 = .195$	0.659

* $p \leq 0.05$

The third step of the analysis was to consider the differences in letter name knowledge between the 6/9 and/or OME group and the 6/6 vision and normal hearing group (Table 18). A higher proportion of children in the 6/9 and/or OME group had low letter knowledge than in the 6/6 vision and normal hearing group ($\chi^2 = 6.164$, $p = 0.013$). As a significantly higher proportion of children in the 6/9 and/or OME group had low IQ scores (22.45%) than in the 6/6 vision and normal hearing group (10.97%), children with low and missing estimated IQ scores were then excluded from the analysis to control for IQ. After the exclusion of the children with low estimated IQs, a significantly higher proportion of children in the 6/9 vision and/or OME group had low letter name knowledge ($\chi^2 = 7.291$, $p < 0.01$). In addition, the mean letter knowledge of the 6/9 vision and/or OME group was significantly lower than that of the 6/6 vision and normal hearing group.

Table 18

The relationship between 6/9 and/or OME group status at school entry and letter name knowledge

	6/9 and/or OME group	6/6 vision and normal hearing group	Analysis
All children			
N	101	166	
Mean letter name score (SD)	11.14 (8.57)	14.78 (8.44)	$t = -3.398^{**}$
Low Letter Name Group (%)	31 (30.69%)	29 (17.47%)	$\chi^2 = 6.302^*$
Excluding low IQ			
N	76	138	
Mean letter name score (SD)	11.95 (8.71)	15.45 (8.17)	$t = -2.932^{**}$
Low Letter Name Group (%)	22 (28.9%)	19 (13.77%)	$\chi^2 = 7.291^{**}$

* $p \leq 0.05$, ** $p \leq 0.01$

The Relationship between 6/9 vision and/or OME Group Status and Letter Name Knowledge, Controlling for Covariates of Emergent Literacy

For the fourth step, the relationship between known covariates of emergent literacy and low letter name knowledge in the participants retained from the previous step (N=214). The covariates selected for this step were those that were significantly associated with low letter name knowledge in the previous analyses. This analysis showed that the covariates of low SES ($\chi^2 = 9.873$, $p \leq 0.01$), low home learning ($\chi^2 = 6.238$, $p \leq 0.05$), behaviour problem ($\chi^2 = 3.506$, $p = 0.058$) and 6/9 and/or OME group ($\chi^2 = 7.291$, $p < 0.01$) were related to low letter knowledge. In single logistic regression model testing, low SES had the highest beta weight ($\beta = 1.090$), followed by low home learning, 6/9 and/or OME group and behaviour problem (Table 19). All of these variables were significantly associated with low letter knowledge ($p \leq .1$) and therefore retained for full model testing.

Table 19

The relationship between 6/9 and/or OME group status, emergent literacy covariates and letter name knowledge

Category	Dichotomization		<i>p</i>
Low SES	Low vs. not-low	1.090	0.002
Low home learning	Scores \geq 1 SD below mean vs. other scores	.946	0.015
6/9 and/or OME group	6/9 and/or B tympanometry vs. 6/6 vision and normal hearing	.937	0.013
Behaviour problem	Scores \times 1 SD above mean vs. other scores	.824	0.066

The fifth step of the analysis was to perform full logistic regression model testing (Table 20). Model 5, which consisted of low SES and 6/9 and or OME, was found to significantly predict low letter name knowledge ($\chi^2 = 13.995$, $p=0.001$) and had an r^2 value of 0.063. The variable of 6/9 and/or OME was found to significantly explain low letter name knowledge (OR= 2.172, CI0.95 = 1.064 ó 4.433) in this model.

Table 20

The relationship between 6/9 and/or OME group status and letter name knowledge, controlling for emergent literacy covariates

Covariates in the Model	Odds Ratio	Lower 95% CI	Upper 95% CI	<i>p</i>
Model 1				
Low SES	2.973	1.481	5.971	0.002
Model 2				
Low SES	2.558	1.240	5.278	0.011
Low home learning	1.957	.881	4.343	0.099
Model 3				
Low SES	2.609	1.279	5.323	0.008
6/9 and/or OME group	2.172	1.064	4.433	0.033
Model 4				
Low SES	2.563	1.251	5.251	0.010
6/9 and/or OME group	2.187	1.067	4.484	0.033
Behaviour problem	2.173	.870	5.427	0.097
Model 5				
Low SES	2.609	1.279	5.323	0.008
6/9 and/or OME group	2.172	1.064	4.433	0.033

Analysis of the Effects of Risk Factors on Letter Name Knowledge

The cumulative impact of emergent literacy risk factors on letter name knowledge was then determined (Figure 4). For the first step of the analysis, children who were at risk due to low SES, low home learning, low IQ, behaviour problems, OME and 6/9 distance vision were excluded. The mean letter name knowledge was 17.92 (SD = 7.10). Children with low SES, low home learning, low IQ, behaviour problems, the OME group and the 6/9 group were excluded from the 0 risk factors group. Children of low SES, were then included (1 risk factor group), followed by those with low home learning (2 risk factors), low IQ (3 risk factors), a behaviour problem (4 risk factors), OME and 6/9 distance vision (6 risk factors). Each successive risk factor had a lower mean letter name score. The mean letter name score of the group of children with all of the risk factors was 13.08.

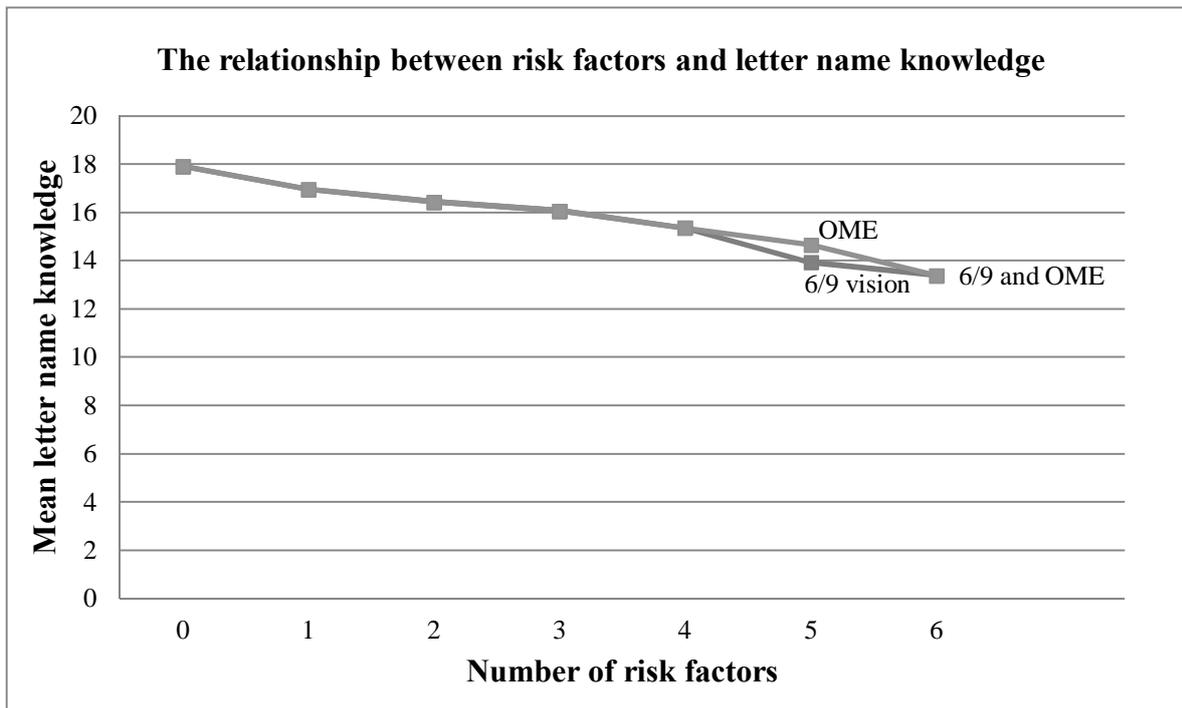


Figure 4 The relationship between the number of risk factors and letter name knowledge

Chapter 5

Discussion

This study was conducted to assess the relationship between 6/9 distance visual acuity and emergent letter name knowledge, and OME and emergent letter name knowledge, in new entrant children, aged 5.

The results of this study showed that children entering school with 6/9-distance vision have significantly lower emergent letter name knowledge than children with 6/6 vision. The bottom quartile for letter name knowledge included children who knew 4 or less letters at school entry. Of the children with 6/9-distance vision, 31.6% were in the bottom quartile for letter name knowledge, as opposed to 18% of children with 6/6-distance vision. Children with 6/9 vision were 2.069 times more likely to be in the bottom quartile for letter name knowledge at school entry, even when considering most other covariates of emergent literacy. In a logistic regression analysis, 6/9-vision was found to significantly explain low letter name knowledge. In addition, the mean letter name knowledge of children with 6/9 vision was 0.5 of a standard deviation lower than the 6/6 vision group.

Children with OME at school entry, or with a history of recurrent OME were also found to have lower letter name knowledge than children in the normal hearing group. Of the children in the OME group, 27% were in the bottom quartile for letter name knowledge, (knew 4 or less letter names), as opposed to 18.6% of children in the normal hearing group. Children in the OME group were 1.8 times more likely to be in the bottom quartile for letter name knowledge, independent of most factors typically identified with literacy difficulties at school entrance. In a multiple regression analysis, past or recurrent OME was found to significantly explain low letter knowledge.

The results of this study also demonstrated that when the risk factors of OME and 6/9 vision were combined, the odds for having low letter name knowledge increased to 2.552. Of the children with 6/9 vision and/or OME at school entry, 28.9% had low letter name knowledge, while 13.77% of the children with 6/6 vision and normal hearing at school entry had low letter name knowledge. The group of children with 6/9 vision and/or OME at school entry had a mean letter name knowledge score that was 0.5 standard deviation lower than children with 6/6 vision and normal hearing. Children with 6/9 vision and/or OME at school entry were more likely to have low letter knowledge independently of factors typically identified with difficulties at school entrance, including low SES, ethnicity, behaviour problems, speech and language problems and home learning support. This is an important finding, as the current study is the first to consider the effects of both current vision and current hearing on the development of emergent literacy. It is also important to consider the importance of having a comparison group with 6/6 vision and without OME.

The findings of the current study are similar to Young et al. (1994) in that a relationship between 6/9-distance vision and beginning reading skill was also demonstrated. However, Young et al. (1994) also demonstrated that 6/7 distance vision could put a child at risk for poor reading development, which may indicate that the cut-off used in the current study was not sensitive enough. It is also important to note that the current study was able to demonstrate that the association between visual acuity and early letter knowledge is independent of other emergent literacy covariates, while Young et al. (1994) did not control for the background characteristics of the sample.

Contrary to the results of the present study, Dirani et al. (2010) reported that 6/9 distance vision at age 9-10 was not significantly associated with low reading achievement. One possible explanation for the differences in the results of the current study and the Dirani

et al. (2010) study is that the participants of the current study were at the 'learn to read' stage, while the participants in Dirani et al. (2010) were aged ten and were likely to have received at least 3 years of formal reading instruction by the time of the study. It was not reported in the latter study whether children had received any remedial reading instruction. Perhaps Dirani et al. (2010) would have supported an association between 6/9 vision and achievement if visual acuity had been assessed at school entry. This pattern has been observed in past literature, where distance vision is most important in beginning reading development (e.g. Chen et al. 2011; Young et al. 1994).

Williams et al. (1988) reported no difference in the reading scores of children with 6/12 vision and 6/6 vision, at ages 7 and 11. The current study, however, found that the letter name knowledge of children with 6/9 vision was lower than children with 6/6 vision. This seems to indicate that the effects of 6/9 vision on literacy are greater than those of 6/12 vision. However, it is likely that the children with 6/12 vision in Williams et al. (1988) had been provided with visual remediation (e.g. glasses) which may have mitigated the effects of distance vision upon reading achievement, while children with 6/9 vision in the current study did not have spectacles or other correction. The difference in the findings of these two studies could also be explained by the younger age and earlier reading stage of the participants in the current study.

Shankar et al. (2007) reported that the mean Letter and Word Knowledge scores of children with near vision refractive error was a standard deviation lower than the comparison group. In the current study, the mean letter name knowledge of children with 6/9 distance vision was 0.5 standard deviation lower than children with 6/6-distance vision. While both Shankar et al. (2007) and the current study reported that children with poor visual acuity knew fewer letter names, the magnitude of the difference observed in Shankar et al. (2007)

was not as marked in the present study. This may be because the current study measured distance visual acuity as compared to near vision acuity in Shankar et al. (2005). These results across studies thus appear to indicate that the effects of near vision problems on reading are greater than that of distance vision. This seems likely, given that children with near visual acuity problems struggle to clearly see the print of books while reading books. It is also important to consider the possible effects of distance vision problems in the Shankar et al. (2005) study which those researchers did not report and given the known relationship between near and distance visual acuity problems (Orfield, Basa & Yun, 2001).

Gravel et al. (1995) reported that the mean letter name scores of children with a history of frequent OME were more than one standard deviation lower than children without recurrent OME, while a difference in means scores was not found in the current study. Perhaps the greater difference in the results of the current study is because in children in the Gravel et al (1995) study with OME at the start of school made less progress during the year, and thus ended the year further behind their non-OME peers than they were at the start of school. The results may also differ because the participants of Gravel et al. (1995) were recruited from a clinic, as opposed to a community cohort in the current study. Therefore the participants of Gravel et al. (1995) may have been predisposed to experience difficulties with learning to read than the participants in the current study.

McCormick et al. (2006) recruited children at birth and monitored them for OME every two to four weeks at home until age 3 years. The percentage of days a child spent with OME in both ears did not explain word identification, reading or passage comprehension scores on the Woodcock Johnson Tests of Achievement at age 7. Similarly, Roberts et al. (2000) found that the percentage of time a child spent with OME in early childhood did not predict performance on the Letter Word Identification sub-test at age 5. The current study,

however, showed that OME did significantly explain low letter name knowledge at school entry, even after considering home learning environments, ethnicity and SES, among other variables. These different results could be explained by the consideration of OME at school entry in the current study, while McCormick et al. (2006) and Roberts et al. (2000) considered only a child's history of OME. These studies may have produced different results had they tested for OME concurrent with literacy assessment. Furthermore, differences in the healthcare received by the samples of children may explain the contrasting results. Very frequent OME screening (fortnightly to monthly) was provided to children in McCormick et al. (2006) and Roberts et al. (2000), but not in the current study. This very frequent screening may have led to better OME identification and treatment, which could have mitigated the effects of OME on literacy development. However, neither McCormick et al. (2006), Roberts et al. (2000) or the current study examined OME treatment and its relationship to letter knowledge at school entry. Therefore the nature of the relationship between OME, hearing screening, OME treatment and emergent literacy remains unclear.

Walker and Wigglesworth (2001) reported that children who had OME in one or both ears at age 5 at kindergarten entry had lower word reading scores in their second year of primary school, as compared to children who did not have OME at kindergarten entry. This finding is similar to the current study, which demonstrated that children with OME at school entry were more likely to have low letter name knowledge than children without OME. However, the results of Walker and Wigglesworth (2001) may be limited because they did not control for factors such as SES, home learning environments and gender, while the current study demonstrated that the relationship between OME and letter name knowledge was independent of these variables, among others.

In addition, Walker and Wigglesworth (2001) reported that children with OME at school entry had poor phonological awareness skill, but did not assess the letter name knowledge of the participants. The current study demonstrated a relationship between OME and letter name knowledge but did not assess phonological awareness. Therefore, there is some evidence that OME at school entry may be associated with both poor phonological awareness and poor letter name knowledge. Phonological awareness and letter name knowledge are known to be associated with each other and develop reciprocally during the early years of literacy instruction (Casardo-Martins et al., 2010). However, further studies into the relationships between these two skills and OME in young children are warranted.

Winskel et al. (2006) reported that children with four or more episodes of OME before the age of 3 obtained mean scores one standard deviation lower than that of the non-OME group. In the current study, children with OME did not have a significantly lower mean letter name knowledge score, but were 1.8 times more likely to be in the bottom quartile. Given the strong association between letter name knowledge and reading outcomes, it is possible that similar results to Winskel et al. (2006) would have been observed in the current study if the children's reading achievement had been assessed a year on, at age 6.

In summary, the results of the current study indicated that children with current OME, a history of OME, or 6/9 distance vision at school entry are at risk for poor emergent literacy at school entry. The result that 6/9 distance vision explained low letter knowledge is a new finding and has not been examined in past research. This is an important finding in the context of the literature on the relationship between distance visual acuity that has received little attention. The effects of distance vision in the current study were demonstrated to be stronger than in many past studies, which may be related to the younger age of the participants. Similarly, the finding of the current study, that OME status significantly

explained low letter name knowledge, is an important contribution to the literature on OME and literature, where the effects of OME on emergent literacy have received little attention. The difference in scores of the OME and control group in the current study was not as substantial in the current study, as in past research (e.g. Gravel et al., 1995), which may have been because the children in the current study had not yet commenced formal reading instruction. The current study also found that children with current 6/9 vision and/or current OME were more likely to have low letter name knowledge than children with 6/6 vision and no OME at school entry. This is important because the current study is the first to include both current vision and hearing in relation to emergent literacy.

The Role of Common Covariates of Emergent Literacy

The current study demonstrated that the relationships between 6/9 vision and letter name knowledge, and OME and letter name knowledge, are independent of most covariates of emergent literacy, including SES, ethnicity, home learning environments, age and gender. The consideration given to factors known to be associated with emergent literacy is a strength of this study, in comparison to many past studies of both OME and vision (e.g. Chen et. al., 2011; Gravel et al., 2005; Orfield et al., 2001; Roberts et al., 2000; Rosner & Rosner, 1997; Winskel, 2006; Walker & Wigglesworth, 2006; Young et al., 1994).

The contributions of IQ and behavior problems warrant further discussion. The relationship between 6/9 vision, IQ and emergent letter name knowledge was unclear in this study. One analysis demonstrated that 6/9 vision explained significant variance in the letter name knowledge of children of average and above estimated IQ (Table 7). However, in another analysis, the covariate of low IQ reduced the significance of 6/9 vision (Table 16), which indicated that low IQ and 6/9 vision share variance in explaining low letter name knowledge. A limitation to note in this regard, however, is the measurement of IQ. There are

very high correlations between the WISC IV and WIAT II psychometric measures (Konold & Canivez, 2010) that were used in this study. Therefore the scores of letter name knowledge and IQ may have been confounded. Although WISC IV sub-tests are commonly used in research as a measure of children's IQ (e.g. Hutchison et al, 2010; Lane et al, 2010), it may have been better to measure letter name knowledge with another instrument that was not so highly correlated with the measure of IQ. In addition, children with 6/9 vision may also have had lower scores on the Block Design sub-test due to their vision. Research has been conducted on the relationship between vision and IQ (Atkinson et al., 2002; Basch, 2011). More research on the relationship between vision, emergent literacy and IQ should be conducted.

Another issue in the findings is the role of behaviour problems. In an analysis, when behavior problems were entered into the analysis, the overall effect of OME on letter name knowledge was reduced (Table 12). In another analysis, however, behaviour problems and OME were both independent of each other in explaining low letter name knowledge (Table 13). This indicated that there are children who have behavior problems who do not have OME, and the scores of these children affected the analysis in Table 12. Whether it is OME or behavior problems that has the strongest relationship to low letter name knowledge in children with both OME and behaviour problems is unclear. It is also unclear as to whether OME at school entry may precede the onset of behaviour problems in school settings. This would be an interesting area of future research.

Strengths and Limitations

One limitation of this study is that the longer-term reading outcomes of the participants were not considered. It is likely that they would have poor reading achievement, given that they were in the lower quartile for letter name knowledge. It is unknown if children in the OME

and 6/9 vision groups were also at risk for poor later reading achievement. If the reading achievement of the participants had been followed longitudinally, the long term effects of OME and 6/9 vision would be better understood.

A strength of this study is that vision and hearing were measured concurrently with letter name knowledge assessment. However, the study is limited by the use of the Parr Test and the Strabismus Screen as the only vision assessments conducted. Given the known association between near and distance visual acuity (Orfield, Basa & Yun, 2001), it is possible that near visual acuity problems, not identified by distance vision screening, also explain the results of this study. Although distance vision testing has a good reliability, it is limited (McGraw, Winn, Gray & Elliot, 2000). Similarly, PTA and tympanometry screens are also limited by not providing a definitive measure of dB loss to hearing. Therefore the results could have been limited by false negative and positive results. This means that the study could have been improved had there been resources for more accurate determination of children's vision and hearing. However, other studies on these conditions and literacy have also used results, without a specialist evaluation (Stewart Brown et al, 1985; Stewart Brown & Brewer, 1986; Dirani, 2010; Young et al, 1994; McCormick et al., 2006). Furthermore, through the use of current screening tests, the results of this study have provided a useful way of identifying children who are at risk for poor reading outcomes, given that this type of screening is performed routinely at school entry in New Zealand. These results are already available to schools and could readily be used to inform early identification of children at risk for reading problems.

Another important strength of the current study is the study recruitment of more than ninety percent (McKenney & Reeves, 2012). This means that the results are likely to generalize to children from a community cohort. This is a particular strength of the study in

comparison to past OME literature, which has often concluded that OME has little effect upon reading achievement for the typically developing child (Lous, 1990). Although the participants were recruited from Christchurch, New Zealand, which is known to comprise a higher proportion of European families and low SES families (Christchurch City Council, 2010; Statistics New Zealand, 2006), the recruitment managed to achieve a proportionate representation of NZ (Liberty et al, 2010). However, the study is limited because of the very low proportion of Asian and other ethnic groups, who are not known to be at risk for poor emergent literacy, in this study indicates that the study population is not representative of many parts of New Zealand. For this reason, and to address other limitations below, the results of the current study require replication with a different group of children and a larger sample.

Finally, additional factors might explain the findings of the current study. Symptoms such as headaches and visual fatigue associated with poor vision might also explain the association between vision and poor reading achievement (Simons, 1993). In addition, children with OME might have poor auditory processing and listening skills because of their OME. This study was limited by not measuring or controlling for these factors.

Implications of the Current Study

The central implication of this study is that highly prevalent vision and hearing problems, commonly experienced during early childhood, can be detrimental to the development of letter name knowledge, even though they are not generally considered to put children at risk for poor literacy outcomes. Visual acuity of 6/9 is considered to be developmentally normal at age 5, not to pose particular risk to a child's vision outcomes and usually does not require visual remediation (Lai, Wang & Hsu, 2011; Pai et al, 2011). The developmental effects of OME have been widely contested in the literature, with many

studies finding no relationship between OME and developmental outcomes (e.g. Roberts et al., 2004). OME is often treated with a watch and wait approach (AAP Clinical Practice Guideline, 2004). However the results of this study indicated that children with 6/9 vision, recurrent OME during early childhood or OME at school entry were more likely to be in the bottom quartile for letter name knowledge. The research literature indicates that children with low letter name knowledge at school entry are less able to benefit from formal reading instruction, are at risk for poor achievement in reading and other areas, and are likely to leave school before their peers (Brynnner, 2008; Foulín, 2005; Stanovich, 1986). Therefore, both 6/9 and OME, which often go unnoticed by parents and/or untreated in early childhood, and which can occur in a significant number of children, could have long lasting effects on children's reading achievement.

If the results of the present study are replicated in future students, one potential implication is that when parents receive vision and hearing screening results from the VHT, they could explain to their child that this might impact their learning to read. They could also discuss the child's vision and hearing with the child's teacher, so that the teacher is notified of the results from the parent as well as VHT notes on school records.

Another possible implication, if results are replicated is that extra support could be provided to help children with OME or 6/9 vision to learn letter names prior to school entry. Emergent literacy interventions often involve the improvement of the opportunities a child has for incidental learning in their own context (Justice & Pullen, 2003). An intervention designed to teach letter names such as that outlined in Graham, Fink and Harris (2008), Conrad and Levy (2001), Justice and Elzell (2002), or Woodrome and Johnson (2009) could be useful in this regard.

In addition, teaching strategies and literacy activities could be adapted to accommodate the limited sensory capacity of young children. For example, the use of bigger letters on a screen and books with large font size could help children with 6/9 vision to develop emergent literacy skills. The use of sound field amplification in the context of typically noisy learning environments could promote the emergent literacy development of children with OME. Such measures could promote the emergent literacy development of children with hearing and vision limitations, and prevent a concerning trajectory of reading failure.

Another important implication of this study is that minor vision and hearing problems may be an underlying factor in the poor emergent literacy skill development and reading achievement of New Zealand children. Up to 10% of children experience significant difficulty learning to read, despite otherwise having normal development (Wang et al., 2011). It is possible that this 10% may partially consist of children who experienced 6/9 vision or OME at school entry. Therefore additional studies that consider the role of OME and 6/9 vision in early literacy should be conducted.

Furthermore, an implication of this study is that models of reading development, which focus on the development of orthographic and phonological processing, should include consideration of a child's vision and hearing. McEneaney, Lose and Schwartz (2001) demonstrated that the dual route processing model of reading development started with visual analysis and phonological analysis (refer Figure 1). The results of the current study indicated that both OME and 6/9 vision independently explained variance in low letter name knowledge. If additional studies replicate these findings, models of reading such as that in McEneaney et al. (2001) would need to be adapted to include the findings. A modified model would include vision quality at the initial stage of the development of the visual (orthographic) pathway, while hearing quality would be included at the initial stage of the

auditory (phonological) pathway, to better reflect the relationship between vision, hearing and literacy development, as illustrated in Figure 5. Future research should be conducted on such a model of reading development that considers vision and hearing at the initial stages of the development of orthographic and phonological processing.

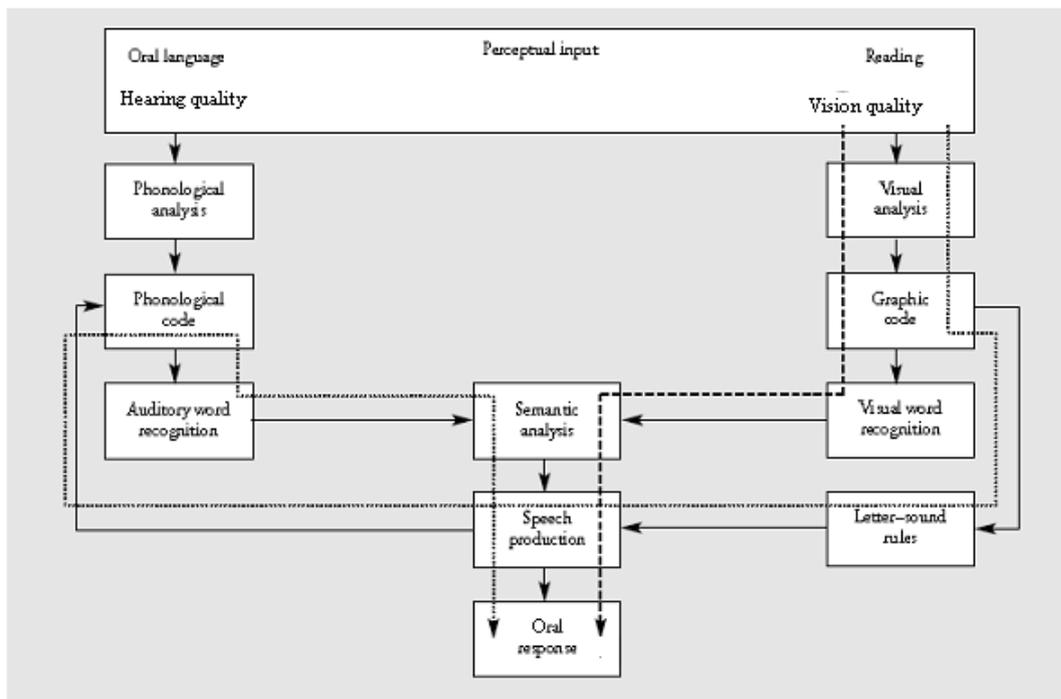


Figure 5 Modified Model of Orthographic and Phonological processing. The results of the present study suggest an adaptation is needed to the theory of phonological and orthographic pathways to reading to include the importance of considering the quality of hearing and vision at the onset of emergent literacy development (adapted from McEneaney, Lose, & Schwartz, 2006).

In addition to consideration of the theoretical underpinnings of early literature, another implication of this study, in conjunction with the reviewed literature, is that future studies on emergent literacy development should report and control for children's past and current vision and hearing limitations. Most past studies on the development of emergent literacy have not tested or reported the vision and hearing of the study participants (e.g., Chatterji,

2006; McDowell, Lonigan, & Goldstein, 2007; Melhuish et al., 2008; Nicholson, 2003, 2008; Pati et al., 2011; Ready et al., 2005; Sénéchal & LeFevre, 2003; West, Denton, Reaney et al., 2000; Whitehurst & Lonigan, 1998). This is concerning, given that vision and hearing problems are correlated with other variables known to be associated with emergent literacy development, such as SES and ethnicity. It is also important to note that these vision and hearing problems may not always be noticeable. Therefore, future research on emergent literacy should aim to detect these vision and hearing problems, as well as control for them, to ensure validity.

Another implication of this study is that future research should assess the long-term reading outcomes for children with recurrent OME during early childhood and OME at school entry or 6/9-vision at school entry. These children may start school with poor emergent literacy, which may put them at risk for poor reading achievement. In addition, their sensory difficulties could affect learning at school. Therefore it is very likely that at least some of these children will have poor reading outcomes. Such research could identify the strength of these factors as predictors. Early childhood vision and hearing screening is a practice that is already in place in New Zealand, and occurs before a child starts formal reading instruction. Vision and hearing screening is conducted currently at age 4.5 or at school entry to identify children at risk for poor sensory development. The use of screening information to inform early reading intervention could be an effective way to improve the reading outcomes of children in New Zealand. Future research is required in this area.

Furthermore, research needs to be conducted to determine the interrelationships between OME, distance vision, and a wider range of emergent literacy skills, such as phonological awareness and letter sound knowledge. This is particularly important, given that there is a reciprocal relationship between phonological awareness, letter sound knowledge

and letter name knowledge (Cardoso-Martins et al. 2011). It is particularly important to understand the inter relationships between these skills to know what type of intervention would be the most effective.

Future research should also assess the relationship between other risk factors for poor emergent literacy development, OME and 6/9 vision. Certain factors may mediate or increase the effects of OME on emergent literacy development. For example, the effects of OME or 6/9 vision upon children from low SES families, who have few literacy resources at home, may be greater than in children from high SES families. This should be examined in future research both with regard to emergent literacy development and reading achievement.

Another important area for future research is to consider the relationship between OME, ethnicity and emergent literacy. A further implication of this study is that the high prevalence of OME in Maori and Pacific Island children (Hill, 2012) could be an important factor as to why these children are often found to have poor emergent literacy and academic achievement in New Zealand (Nicholson, 2003; 2004). OME was found to be more strongly associated with low letter knowledge than minority ethnicity in this study, although OME is inconsistently related to Maori and PI ethnicity (Gribben et al, 2012). This could indicate that OME is a moderator variable through which Maori and Pacific Island children come to have low letter name knowledge. Future studies should be conducted to better clarify the association between OME, ethnicity and literacy development.

Conclusion

The results of this study have identified two important risk factors for poor emergent literacy development; 6/9 distance vision and OME status. Furthermore, a strength of the current study is that the results demonstrated that over 30% of children with OME, 6/9 vision, or both, were in the bottom quartile for letter name knowledge at their entry to school. This

finding is a contribution to the current literature, and in understanding the bio-physiological basis for poor readiness to read. Therefore, this study could have wide reaching implications if future studies of early literacy include measures of vision and hearing, given that literacy is known to predict future school performance, self-esteem, societal inclusion and employment prospects (Brynnner, 2008; Snow, Burns, & Griffin, 1998; Stanovich, 1986; Torgesen, 1998), future studies of children with 6/9 vision and OME, could help ensure that children at risk for poor literacy outcomes are given the support they require, to prevent the onset of a reading failure trajectory, due to a vision or hearing problem.

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