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Vision screening outcomes of Grade 3 children in Australia: Differences in academic achievement

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ABSTRACT

Learning is multisensory, thus impaired vision may impact on classroom learning and subsequently, academic achievement. This research investigated the impact of impaired vision on academic achievement in a sample of 109 Grade 3 Australian children. Approximately 30% of the sample were identified as borderline or unsatisfactory by a vision screening and were referred for a full eye examination. Children who were referred at the vision screening scored significantly lower on national standardised tests of reading, grammar and punctuation, spelling and numeracy, when compared to their not referred peers. This research has important implications for teachers and eye health professionals, as the findings highlight the importance of early vision screening in identifying children who may be achieving below their potential.

1. Introduction

Multisensory stimulation is essential in early development, as it encourages learning and brain plasticity (Shams & Seitz, 2008). For example, reading and spelling are inherently multisensory, requiring processing of both phonological (verbal) and orthographical (visual) representations (Labat, Ecalle, Baldy, & Magnan, 2014). Impairment in any one of the sensory systems is thus likely to impact on cognitive processing and learning. The current study addressed this issue with a specific focus on the role of the visual system, by exploring the impact of impaired vision on academic achievement in primary school aged children.

Recent studies suggest that the visual demands of the classroom are likely to contribute to a child's early learning and achievement. When preparing classroom lessons, the importance of visual attention is well established (Fisher, Godwin, & Seltman, 2014), however, teachers assume that children possess the visual capabilities required to take advantage of in class learning opportunities. These opportunities might include the ability to rapidly change focus from near to distance, as required when changing visual attention from workbooks to the board, or sufficient colour vision discrimination to distinguish colours that a teacher might use to highlight important information. Indeed, a recent study of Grade 5 and Grade 6 Australian classrooms suggested that up to 70% (263 ± 37 min) of daily classroom time involved academic related tasks with visual input (Narayanasamy, Vincent, Sampson, & Wood, 2016). These visual related academic tasks were shown to

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largely involve near tasks (47%), distance tasks (29%), distance to near tasks (15%), and computer tasks (9%) (Narayanasamy et al., 2016). For example, children who are long sighted and not wearing appropriate spectacles (uncorrected hyperopia) may experience blurred vision at near and eye strain, which could affect their ability to complete near tasks (e.g. reading), which constitute a large proportion of academic related tasks, thus limiting their opportunities to learn and achieve their full potential. Indeed, Thurston (2014) in his review of this area highlighted the importance of a visual system that is optimally focused (visual acuity and refraction), free of any eye disease, uses efficient and coordinated eye movements to scan and quickly change focus over a range of working distances, with appropriate cortical integration and processing of visual input. These key visual components are necessary before any higher level cognitive processing can occur (Paivio, 2013).

While a large body of research has investigated the impact of vision impairment on academic achievement in school aged populations, the findings are mixed and dependent on which specific visual functions were assessed and the academic outcome measures employed (e.g. Hannum & Zhang, 2012; Kulp et al., 2016; Ma et al., 2014; Roch-Levecq, Brody, Thomas, & Brown, 2008; Yi et al., 2015). Given the importance of multisensory stimulation in early reading development, the Vision in Preschools – Hyperopia in Preschoolers (VIP-HIP) Study (Kulp et al., 2016) reported interesting findings regarding the role of accurate visual focusing on literacy performance, particularly in light of the relatively high level of near work involved in modern classrooms (Narayanasamy et al., 2016). Kulp et al. (2016) found that overall, preschool children with uncorrected hyperopia scored significantly worse on the Test of Preschool Early Literacy (TOPEL) when compared to children who were emmetropic (no refractive error). Further analysis of the TOPEL subtests (print knowledge, definitional vocabulary and phonological awareness) showed that children with uncorrected hyperopia performed significantly worse on the print knowledge subtest (Kulp et al., 2016). This indicates that uncorrected vision impairment may differentially contribute to learning outcomes dependent on the visual demands of specific tasks. For example, print knowledge requires visual identification and distinguishing of written letters (e.g. distinguishing *p, d, q, and p*) and words, whereas the phonological awareness subtest is conducted verbally with no written (visual) element. In a study of Grade 4 and Grade 5 Chinese children, Yi et al. (2015) reported that 24% had reduced habitual visual acuity and that poor vision was associated with reduced mathematics achievement. Importantly, in both the Kulp et al. (2016) and Yi et al. (2015) studies only one academic domain was selected as an indicator of overall academic achievement. The association between vision impairment and academic achievement therefore requires further detailed examination across multiple academic domains that involve a range of visual demands.

Another area that represents a gap in evidence is the wide variation in the vision screening protocols used to assess children in the early stages of school. Many vision screenings concentrate on assessment of distance vision, with minimal consideration of near visual functions, which are arguably the visual skills most relevant to classroom performance (Hopkins, Sampson, Hendicott, & Wood, 2013). In Hopkins et al's (2013) review of children's vision screenings, it was demonstrated that the eye conditions most commonly targeted were amblyopia (lazy eye) and its risk factors, focusing errors, colour vision deficiencies and eye disease. This review concluded that there is a lack of a universally agreed policy or strategy around children's vision screenings in Australia and other countries, most likely due to the paucity of evidence available on which to base screening protocols (Hopkins et al., 2013). Importantly, early detection of visual problems depends on and impacts upon both education and optometry professionals. Vision screening of a large sample (n = 2697) of Australian children aged 3–12 years, identified approximately 27% of children (n = 669) as having borderline and unsatisfactory visual outcomes, with nearly 20% being referred for further assessment, while 7% were already under the care of an eye care professional (Junghans, Kiely, Crewther, & Crewther, 2002). In the majority of cases, children were referred because of binocular vision anomalies (poor eye coordination), focusing errors or a combination of the two, which all contribute to a child's visual efficiency and ability to achieve comfortable, clear, single vision. Given that around 1 in 4 children were identified as having vision problems in these screenings (between 20% and 30%) (Junghans et al., 2002), it is possible that they may also have experienced difficulties with the visual demands of school based learning, resulting in academic achievement that was below their true potential.

The present research addressed some of the gaps in knowledge regarding the association between vision screening outcomes and academic performance in primary school children. The aim of this study was to undertake a clinical vision screening assessment in a cohort of Grade 3 children, to identify those with uncorrected vision problems, including assessment of both distance and near visual function. The links between the referral outcomes of the vision screening and academic achievement were explored using a national standardised test related to early literacy and numeracy.

2. Methods

2.1. Schools

Three schools agreed to participate in this study through contact by the authors at a regional cluster meeting. The schools were medium large government primary schools from the outer north metropolitan region of Brisbane, Australia, each with enrolments of above 500. All three participating schools had Index of Community Socio-Economic Advantage (ICSEA) values between 940 and 986; all below the national mean of 1000. The ICSEA values are derived from both community- and child-level data. Child-level data includes parent occupation and education, while community-level data includes remoteness and percent Indigenous enrolment. With a national mean of 1000 (±100), ICSEA values range from approximately 500 (schools with children with extremely educationally disadvantaged backgrounds) to approximately 1300 (schools with children with very educationally advantaged backgrounds). The ICSEA for each participating school was used to enable fair and meaningful comparison of academic performance between schools with similar children enrolled (Australian Curriculum, Assessment and Reporting Authority, 2015).

2.2. Participants

In the three primary schools, all Grade 3 children (n = 282) were invited to be involved in the research project. A total of 109 Grade 3 children (mean age: 8.7 ± 0.3 years; range: 8.1 years to 9.5 years; 61 females; 48 males) agreed to participate in the study and completed all aspects of data collection. Consent was obtained from both parent/guardian and child.

2.3. Ethics

All procedures in this research were conducted in accordance with the ethical standards of the institutional and national research committee. The study was approved by University Human Research Ethics Committee which operates within the Australian National Statement on Ethical Conduct in Human Research (National Health and Medical Research Council, 2015). Approval to conduct research in Queensland State Schools was also granted by the Queensland Government, Department of Education and Training.

2.4. Vision screening

Each child underwent a vision screening performed by optometry students closely supervised by an experienced paediatric optometrist. A brief case history was obtained to document any relevant eye symptoms. The following vision tests were performed as part of the screening: distance vision in each eye using a standard letter chart at four metres (distance visual acuity), distance vision through plus (+1.50D) lenses (a test for hyperopia), retinoscopy (a measure of focusing or refractive error, such as hyperopia, myopia or astigmatism), colour vision assessment (Ishihara test), stereo vision (depth perception) using a Titmus stereotest (graded circles and fly), binocular vision testing (eye coordination) using a cover test, and an ocular health screen through direct ophthalmoscopy. All vision tests were undertaken with a child's existing spectacles, if used in the classroom. Screening outcomes were classified as satisfactory, borderline or unsatisfactory, guided by the clinical findings from the screening tests. Potential reasons for a borderline or unsatisfactory classification included focusing errors (refractive error) and reduced distance vision (visual acuity), presence of binocular vision anomalies, abnormal ocular health and/or colour vision defects. The supervising optometrist examined the clinical findings for each child on a case-by-case basis, and made a clinical decision regarding whether the child should be referred (either unsatisfactory or borderline) for a full eye examination or not (satisfactory). This approach was based on the Orinda Modified Clinical Technique, which has been reported to have very high levels of specificity and sensitivity (Blum, Peters, Bettman, Fellows, & Johnson, 1959). For the current study, determination of the screening outcomes was based on the complete clinical profile of each child, using similar cut-off values to those adopted by Junghans et al. (2002).

2.5. Achievement

For each child, scaled achievement scores were collected from the National Assessment Program for Literacy and Numeracy (NAPLAN). NAPLAN is a standardised suite of tests completed by all Australian children in Grades 3, 5, 7 and 9. NAPLAN is not focused on content, but rather literacy and numeracy developed throughout schooling and is linked to the Australian Curriculum. There are five subtests that are completed in four testing sessions: reading, writing, language conventions (spelling, grammar and punctuation) and numeracy. Each testing session is around 45mins in duration, formally administered in each school with scoring completed by the test administration authority in each state. The administering body of NAPLAN, Australian Curriculum, Assessment and Reporting Authority (ACARA) reports children's results as scaled scores ranging from 0 to 1000, with corresponding bands 1–10, which indicates how children perform compared to established national standards, mapped across Grade 3 to Grade 9.

The children in the current study completed all Grade 3 NAPLAN subtests, which are reported to have good internal reliability (reading $\alpha = 0.88$; writing $\alpha = 0.96$; spelling $\alpha = 0.92$; grammar and punctuation $\alpha = 0.79$; and numeracy $\alpha = 0.86$; Australian Curriculum, Assessment and Reporting Authority, 2015). The NAPLAN assessments were completed over two consecutive days in May, approximately four months prior to the vision screening.

2.6. Data analysis

All statistical analyses were completed using SPSS (ver 23.0, www.ibm.com/spss). Descriptive statistics were used to describe NAPLAN performance across all tests (reading, writing, spelling, grammar and punctuation, numeracy). Univariate analysis of covariance was conducted to examine the differences between the NAPLAN test scores between children with different vision screening outcomes (referred or not referred), with adjustment for potential covariates of ICSEA and age.

3. Results

3.1. Vision screening

The vision screening identified 27 children (24.8%) who were classified as unsatisfactory, and six (5.5%) who were classified as borderline. All of these children (n = 33, 30.3%) were subsequently referred for a full eye examination. The primary reasons for referral included focusing errors (refractive error) and reduced visual acuity (n = 21), presence of binocular vision anomalies (n = 7), abnormal ocular health (n = 3) and presence of colour vision defects (n = 2).

3.2. Vision screening and achievement

Overall, the children in the whole sample were achieving below national means for the Grade 3 NAPLAN assessments, however, when compared to schools with similar ICSEA, their NAPLAN scores were within a similar range (Table 1). In all components of the NAPLAN tests, those children who were referred for a full eye examination (unsatisfactory or borderline from the vision screening) scored lower than the children who were not referred. In the ANCOVA models adjusting for age and ICSEA, scores for all NAPLAN tests, except writing, were significantly lower (worse performance) in children who were referred, compared to those who were not referred ($p < 0.04$; Table 1). The largest difference identified between the two groups was for the grammar and punctuation test, where children who were referred were nearly 57 units lower in their NAPLAN scaled scores. Similarly, the children who were referred were 47 and 46 units lower in spelling and numeracy scaled scores, respectively, when compared to their peers who were classified as satisfactory for the visual screening. Interpreting these significant differences in terms of NAPLAN achievement bands, the group mean for the children who were referred sits within band 3, while the group mean for the children who were not referred was a single band higher (band 4; Table 1).

4. Discussion

This research demonstrated that the academic achievement of Grade 3 children referred following a vision screening was significantly lower on national standardised tests of literacy and numeracy, when compared to children not requiring a referral. In our cohort, approximately 30% were referred for a full eye examination because their vision screening outcomes were unsatisfactory or borderline. Children were predominantly referred for reduced visual acuity, potential uncorrected refractive error and problems with eye coordination. The proportion of referrals identified in our study (around 30%) is slightly higher than vision screening fail rates reported in other studies both from Australia and internationally (e.g., Junghans et al., 2002; Yi et al., 2015). This variability may be attributable to regional or age related variations. For example, the current finding is for children in Grade 3 with a mean age of 8.7 ± 0.3 years, whereas another Australian study conducted in a different region (Junghans et al., 2002) had a larger sample of children but across 3–12 years of age and reported a lower 20% referral rate. Notably, the schools included in the current research fell within a lower socioeconomic age category, where there is often a higher prevalence of uncorrected visual impairment (e.g., Majeed, Williams, Northstone, & Ben-Shlomo, 2008).

Importantly, the children referred for a full eye examination scored significantly lower than those children who were not referred in all NAPLAN subtests, except writing. The lower scaled scores and achievement bands suggest that visual difficulties may be limiting classroom learning opportunities and impacting on the academic competencies of the children in the present study. The widest achievement gap between referred and not referred children was evident in the assessments of spelling and grammar and punctuation. In language conventions (spelling, grammar and punctuation) band 3 skills are

Table 1
Comparison of NAPLAN assessment scaled scores based on vision screen outcome (total sample and referred/not referred groups), including schools with similar ICSEA and the Australian national mean.

Subtest	Total Sample M ± SD n = 109	Referred Group M ± SD (band[a]) n = 33	Not referred Group M ± SD (band[a]) n = 76	$F(1,105)$	p	η_p^2	Schools with similar ICSEA (ACARA, 2015a, 2015b)	National mean (ACARA, 2015a, 2015b)
Reading	392 ± 97	365 ± 82 (band 3)	404 ± 101 (band 4)	4.568	.035	.04	388–414	418
Writing	379 ± 65	369 ± 60 (band 3)	383 ± 67 (band 3)	1.787	.184	.02	376–398	402
Spelling	392 ± 94	359 ± 98 (band 3)	406 ± 90 (band 4)	5.964	.016	.05	381–405	412
Grammar & Punctuation	399 ± 93	360 ± 107 (band 3)	416 ± 81 (band 4)	9.920	.002	.09	391–418	426
Numeracy	383 ± 78	351 ± 70 (band 3)	397 ± 78 (band 4)	9.125	.003	.08	377–399	401

[a] Mean scaled scores for each group were used to determine corresponding achievement bands (ACARA, 2014).

described as *identifying errors and correctly spelling one-syllable words and recognising written language conventions (capital letters, full stops and question marks) in short sentences,* whereas band 4 skills are described as *identifying errors and correctly spelling most one- and two-syllable words and recognising written language conventions (adjectives, pronouns and capital letters for proper nouns) in short sentences and speech* (ACARA, 2015b). This comparison shows that the children who were not referred demonstrated more complex cognitive processing than children who were referred following a vision screening.

Our findings align to some extent with those of the VIP-HIP study (Kulp et al., 2016), which found that 4 and 5 year old preschoolers with uncorrected hyperopia scored significantly worse on the print knowledge subtest of the Test of Preschool Early Literacy, compared to emmetropic children (with no refractive error). In the current study and the VIP-HIP study, vision appears to be an essential sensory input for achievement for spelling, grammar and punctuation, and print knowledge. Reading and spelling are inherently multisensory, and require the integration of phonological (verbal) and orthographical (visual) representations (Labat et al., 2014). Difficulty accessing essential visual information is thus likely to create challenges when developing reading skills, which is supported by our findings.

In numeracy, our findings show that children referred at vision screening achieved in a lower band and had a mean scaled score 46 units lower than their not referred peers. In the numeracy subtest, band 3 achievement is described as *solving single-step problems involving addition, subtraction or simple multiplication*, whereas band 4 describes more advanced *problems solving involving fractions and combinations of addition and subtraction of two-digit numbers and number facts to 10* × *10* (ACARA, 2015b). The lower numeracy scaled scores of children who were referred at vision screening suggest that these children may be at a relative disadvantage for developing their numerical competencies, given the increased difficulty accessing essential visual information due to potential uncorrected vision problems. Problems with focussing or binocular coordination may increase difficulty in identifying and distinguishing between some numbers (e.g. distinguishing between 3 and 8, or 1 and 7), particularly when vision is blurred or the visual system is fatigued, which might impact on attainment and progression in mathematics. This finding parallels those of Yi et al. (2015), who reported a decline in mathematics achievement corresponding to decreased vision in Grade 4 and 5 children.

Importantly, Narayanasamy et al. (2016) reported that up to 70% of classroom time is dedicated to a variety of academic related tasks that require visual input, particularly at near, therefore children referred at vision screening due to potential uncorrected vision problems could be at a substantial learning disadvantage. This disadvantage from uncorrected vision problems is likely to be further exacerbated during the early years of school, when children are learning to read both letters and numbers. Without important reading foundations, a child's long term learning trajectory may be compromised. Indeed, data from the Early Childhood Longitudinal Study – Kindergarten Class (ECLS-K) indicated that Grade 1 children with reading problems were significantly more likely to demonstrate poor task engagement and poor self-control in Grade 3 classroom learning (Morgan, Farkas, Tufis, & Sperling, 2008). As such, comprehensive vision screening on entry to formal schooling, as well as ongoing monitoring throughout school years, is necessary to ensure that children have the best start in schooling. This has important implications for both education and eye health professionals.

A key strength of the current research is that academic achievement was measured across multiple domains (reading, writing, spelling, grammar and punctuation, numeracy) using a national standardised achievement test. The differences in achievement between children who were referred and not referred at vision screening can be interpreted alongside national curriculum expectations and inform classroom practice. However, it is important to acknowledge that this study was limited to some extent by its relatively small sample size (n = 109) of children from three schools. Furthermore, no details regarding the results of the subsequent full eye examinations for those who were referred were available. Future studies should include larger sample sizes of children from a wider range of schools, including more comprehensive visual information for both the referred and not referred children. Given that the current research was cross-sectional in nature, future research should also include longitudinal tracking of children to capture changes in learning trajectories that result from early identification of specific vision impairments. The protocols for eye examinations with young children also need further systematic investigation and to be evidence based and standardised rather than varying between countries and states, as suggested by Hopkins et al. (2013).

In summary, the current study provides evidence that children who were referred following a vision screening have significantly reduced academic achievement levels than their peers who were not referred. This highlights the importance of vision screenings in identifying children at risk of underachieving in the classroom. This has direct implications for policy makers, given that, historically, cost benefit analysis of publicly funded paediatric vision screening has focused on vision related outcome measures. Additional consideration should be made regarding the potential impact on teaching and learning, as well as learning related outcomes and longer term quality of life outcomes. These findings are important, not only in terms of screening children for visual problems early, but also correcting vision problems to ensure optimal functioning in the classroom environment and opportunities to learn. Awareness also needs to extend beyond eye health professionals and include policy makers, as well as teachers and the wider community.

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