Taylor & Francis
Taylor & Francis Group

Clinical and Experimental Optometry

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tceo20

Visual acuity and reading print size requirements in children with vision impairment

Lynne Loh, Mallika Prem-Senthil & Paul A Constable

To cite this article: Lynne Loh, Mallika Prem-Senthil & Paul A Constable (12 Nov 2023): Visual acuity and reading print size requirements in children with vision impairment, Clinical and Experimental Optometry, DOI: 10.1080/08164622.2023.2279190

To link to this article: https://doi.org/10.1080/08164622.2023.2279190

Published online: 12 Nov 2023.

CLINICAL AND EXPERIMENTAL OPTOMETRY
https://doi.org/10.1080/08164622.2023.2279190

Optometry AUSTRALIA | Taylor & Francis Taylor & Francis Group

RESEARCH

OPEN ACCESS | Check for updates

Visual acuity and reading print size requirements in children with vision impairment

Lynne Loh, Mallika Prem-Senthil and Paul A Constable

College of Nursing and Health Sciences, Caring Futures Institute, Flinders University, Bedford Park, South Australia, Australia

ABSTRACT

Clinical Relevance: The support of students with a vision impairment throughout education could be enhanced by assessing the functional reading ability of the individual. This visual assessment could inform educators of individualised student needs and potentially improve the academic achievement for these students.

Background: Support for children with a vision impairment within a classroom is typically based on clinical findings of distance visual acuity and visual fields. Therefore, determining optimal print size for reading is essential to ensure best academic outcomes. Secondary aims were to investigate the possible impact of underlying pathology on reading ability.

Methods: Forty-seven participants were recruited from a state-wide support service for children with a vision impairment in South Australia. Three visual acuity groups were formed based on World Health Organisation definitions of mild, moderate, and severe vision impairment. Correlation between clinical measures of distance visual acuity using the Freiburg Visual Acuity Test, were compared with reading acuity and critical print size (smallest font before reading speed reduced) using Minnesota low vision reading chart (MNREAD).

Results: No significant correlations were found for mild (0.20–0.49 logMAR) and severe (1.00–1.52 logMAR) vision impairment groups between distance visual acuity and reading acuity read ($p = .64$, CI [−.585, .395]/$p = .82$, CI [−.48, .58]) or critical print size ($p = .78$, CI [−.57, .45]/$p = .43$, CI [−.34, .68]). A significant correlation was found for the moderate vision impairment group: 0.50–0.99 logMAR for minimum reading acuity ($p < .001$, CI [.44, .91]) and critical print size ($p = .03$, CI [.05, .80]).

Conclusions: Standard clinical measures of distance visual acuity are an unpredictable estimate of reading ability in children with mild and severe vision impairment. Additional measures of functional near reading ability could provide a more meaningful indicator of reading ability and help provide optimum support to students through education.

ARTICLE HISTORY
Received 19 December 2022
Revised 7 August 2023
Accepted 30 October 2023

KEYWORDS
Education; font size; low vision; reading ability; reading performance

Introduction

Blindness and vision impairment can significantly impact the social development of a child, academic achievement, and self-esteem, particularly in an educational environment.[1] The global prevalence of childhood vision impairment is estimated to be 19 million, with a high proportion (31%) due to inherited retinal conditions.[2–4] The main causes of childhood vision impairment in developed countries are cerebral vision impairment, optic nerve anomalies, albinism, and inherited retinal dystrophies.[2–9]

Vision impairment is typically based upon the World Health Organization (WHO) definitions, with visual acuity 6/12 to 6/18 (0.30–0.50 logMAR) defined as mild impairment, 6/18 to 6/60 (0.50–1.00 logMAR), moderate impairment and 6/60 to 3/60 (1.00–1.30 logMAR) as severe. Blindness is defined as presenting visual acuity less than 3/60.[10] Vision below the level of 1.00 logMAR (6/60 or worse) is considered legally blind in many countries and qualifies the individual to register for support, which currently includes the Blind Pension (Australia), Federal and State Benefits (USA) or Disability Living Allowance (UK).

Support for children with a vision impairment, within the classroom environment, is typically based upon clinical measures of high contrast distance visual acuity and, where possible, a visual field assessment. The assumption being that, as with normally functioning eyes, distance visual acuity correlates with near visual acuity and subsequently readable font size. Consideration of additional factors that can impact a paediatric vision assessment include testing methods, environmental conditions, oculomotor control, visual field size and childhood behaviours, which may impact distance acuity measures.[11–13] Reduced contrast sensitivity may also reduce reading speed, especially if the print quality is poor.[14] Outside of a clinical study setting, such as in the classroom, consideration of these factors may not be applied consistently and reduce the ability for a child to access learning materials.

Near acuity is defined as the reading acuity that can be read at the habitual reading distance. Typically, distance and near acuity are related so that a distance visual acuity 0.00 logMAR corresponds to a near reading font size of 3.7-point print at 40 cm. However, it is also important to consider optimum font size that can be read comfortably, without reducing reading speed or causing excessive strain, to ensure that students with a vision impairment can sustain reading throughout the course of the school day.

Reading and literacy skills have been shown to be a good indicator of future academic performance,[15,16] and most

CONTACT Lynne Loh lynne.loh@flinders.edu.au

Supplemental data for this article can be accessed online at https://doi.org/10.1080/08164622.2023.2279190.

learning time within a classroom is based around near vision tasks, predominantly allocated to reading and writing.[17] Previous studies have highlighted the impact of childhood vision impairment on reading speed, with the consensus of findings demonstrating a slower reading speed in children with a vision impairment compared with age matched normally sighted children.[18–24] Studies have also investigated the difference in reading characteristics between children with a vision impairment and their normally sighted peers, including the role of phonology and reading comprehension. These studies found that children with a vision impairment employ the same reading strategies and have the same comprehension ability – but are only limited by the speed at which they read.[18,19,23,24]

Previous research has also indicated an association between low vision and reduced academic performance, based on classroom grades and national testing results.[25,26] Therefore, determining the optimum print size for an individual with a vision impairment, that can be read at maximum speed, is critical to their ability to engage effectively within the classroom learning environment and achieve their full academic potential.

Font size and reading speed are intrinsically linked; if font size is too large, then reading speed is slower due to a reduced number of words on a page and the individual is required to scan more.[27] As large font size is reduced, reading speed increases until the maximum reading speed is achieved, where it stays relatively constant across several font sizes. As resolutions limits are neared, the reading speed slope drops sharply until resolution limits are reached and the individual is unable to resolve the smaller font to continue reading. Critical print size is used to determine the font size for a child with a vision impairment to use within the classroom to achieve optimum reading performance.

The main aim of this study was to evaluate the relationship between distance visual acuity and print size reading ability in children with a vision impairment. Secondary aims were to investigate the possible impact of underlying pathology on reading ability.

Methods

Participants

Seventy children were recruited from a state-wide support service for children with a vision impairment South Australia. All children had previously been diagnosed, by an ophthalmologist, with a pathological vision impairment. Eligible children, in full time education, were identified by specialist low vision trained state-wide support teachers in South Australia. Since the Minnesota low vision reading chart (MNREAD) uses vocabulary from high frequency words used in reading material of 8-year-old children, students were only included if their teacher reported a reading age of eight years and above.

Children were excluded ($n = 23$) if they had a diagnosis of dyslexia, language or communication disorder, intellectual disability (IQ < 75) or were unable to read the largest font sentences on the MNREAD chart at 10 cm.

Distance visual acuity

Habitual refraction was worn for distance and reading analysis as required. Binocular distance visual acuity was measured using the Freiburg Visual Acuity Test (FrACT).[28] FrACT uses a four-alternative forced-choice paradigm using Landolt rings making it suitable for young children and can quantify vision at the lower end of the visual acuity range which has traditionally been given a semi-quantitative value (i.e. hand movements or count fingers).[29] There is also no clinically significant difference between visual acuity measures using FrACT Landolt C and ETDRS charts.[30]

Visual acuity groups

Based on the level of binocular distance visual acuity, participants were grouped into three levels for analysis. The visual acuity groups were defined based on the definitions of mild, moderate, and severe vision impairment by the WHO.[10] Group-severe: 1.00–1.52 logMAR (6/60–6/190), group-moderate: 0.50–0.99 logMAR (6/19–6/60), and group-mild:0.20–0.49 (6/9–6/18).

The forty-seven eligible participants (28 male and 19 female) with age (mean ± SD) 12.2 ± 3.0 (range 5.0–18.0) and school grade 6.3 ± 3.1 (Reception to grade 12) underwent clinical measures of distance visual acuity and full reading analysis. Pathological causes of vision impairment were predominantly inherited retinal dystrophies (34%) or albinism (28%) optic nerve disorders, including optic nerve hypoplasia, optic nerve glioma and optic neuropathy accounted for 15% of participants. Two participants had retinopathy of prematurity and one each had aniridia, iris/choroid coloboma, uveitis, retinal detachment, congenital glaucoma and congenital cataracts. Idiopathic infantile nystagmus was present in three participants, with overall presence of nystagmus secondary to primary pathology in 83% of the participants (see Figure 1). There were no significant differences ($p > .08$) between groups for sex, age, academic year, or nystagmus present (See Table 1). An analysis of pathology by each visual acuity group is included in supplementary material.

Reading performance

Reading analysis was performed using the MNREAD[31] on an iPad7, iOS version 14.4.1. MNREAD was used to assess reading acuity read (the smallest print size that can be read without significant errors) and critical print size (the smallest font size read at maximum reading speed).[32] The iPad was mounted in landscape mode and the reading distance constantly monitored by a fixed ruler. Reading distance was fixed at 40 cm unless the student was unable to read the largest font at this distance, whereby the reading distance was halved. Sentence presentation was initiated and stopped by the examiner to control the accuracy of timing. Reading tests were performed with different sentence sets to avoid memorisation and an average of results taken. Room illumination was kept at a constant classroom level of between 450–500 Lux.

For comfortable, sustained reading performance, the measurement of reading acuity is not as important as the critical print size,[20,27,33] which is the smallest font size before reading speed begins to decrease. It is defined as the print size at which subsequent smaller print sizes were read at 1.96 standard deviations slower than the mean of the preceding print sizes.[31] For further details on the MNREAD, see supplementary material.

Statistics

Relationships between distance visual acuity and reading performance (reading acuity and critical print size) were evaluated using Pearson's correlation coefficient. All analyses

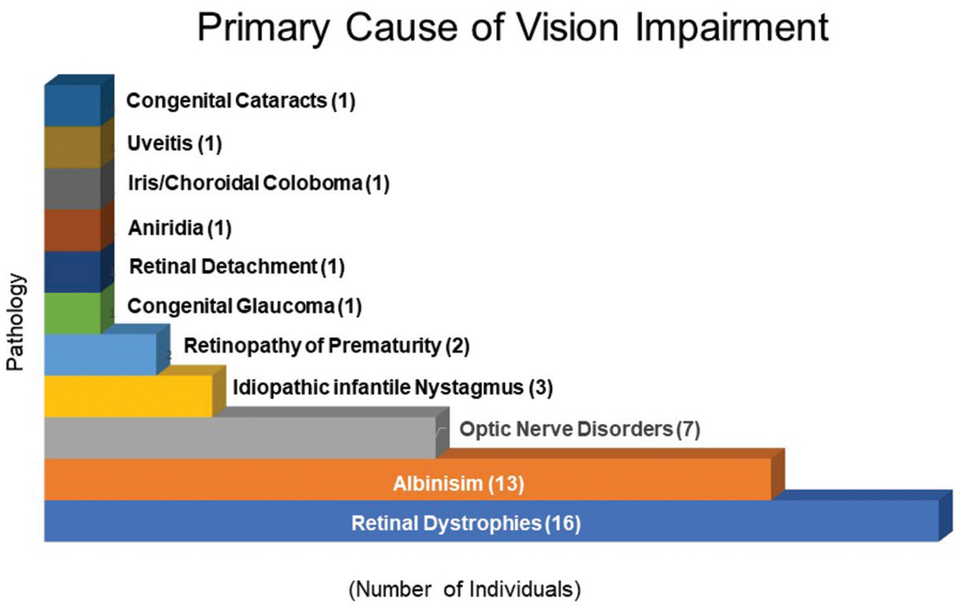

Figure 1. Distribution of the primary cause of vision impairment in the study population with the majority being due to either an inherited retinal dystrophy or albinism.

Table 1. Characteristics of the vision impairment study population by visual acuity group. All values are mean ± SD. CS Contrast Sensitivity, *M* = male, F = female.

	All ($n = 47$)	Group-severe ($n = 16$)	Group-moderate ($n = 17$)	Group-mild ($n = 14$)	*p*
Sex (M:F)	28:19	12:4	11:6	5:9	.08
Age (years)	12.2 ± 3.0	12.5 ± 2.9	11.9 ± 3.0	12.5 ± 3.2	.97
Academic Year	6.3 ± 3.1	6.7 ± 2.9	6.0 ± 3.3	6.4 ± 3.2	.42
Nystagmus Present %	83	70	94	86	.15
Log CS Threshold	1.25 ± 0.45	1.02 ± 0.36	1.21 ± 0.41	1.56 ± .43	.006

were performed using IBM SPSS version 28. A *p*-value of < .05 was taken as significant. Non-parametric tests (Chi-Squared Test of Independence, Kruskal-Wallis Test) were used as appropriate to compare parameters between the three acuity groups. All values are reported as mean ± standard deviation (SD) unless otherwise specified.

Ethical approval

This study was approved by the Women's and Children's Health Network, Human Research Ethics Committee, South Australia, and the South Australian Department of Education. All children and parents gave informed written informed consent prior to participation.

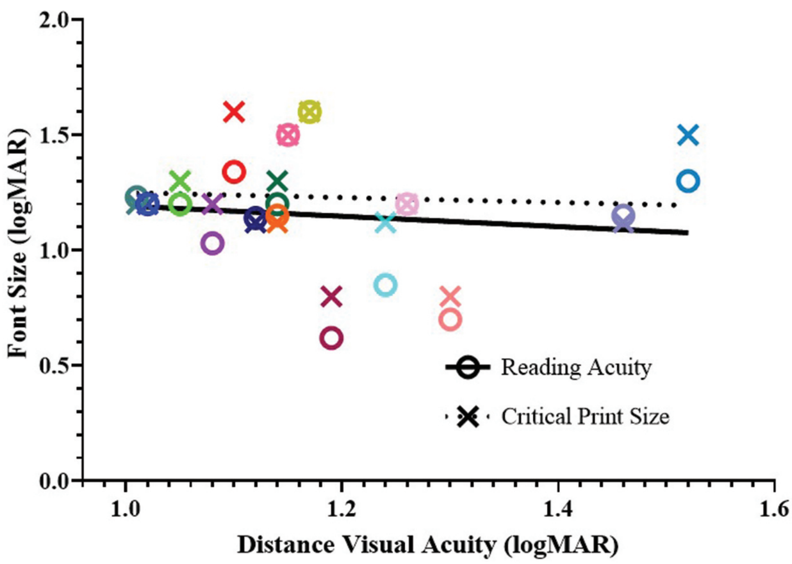

Figure 2. Relationship between reading acuity (circles), critical print size (crosses) and distance visual acuity for $n = 16$ subjects in group-severe. Each colour represents an individual subject. No significant correlations were found in the acuity range 0.20–0.49 LogMAR for minimum reading acuity ($p < .82$) or critical print size ($p < .43$). With regression lines for reading acuity (solid line) and critical print size (dotted line).

Results

Distance visual acuity and reading performance

Group-severe participants demonstrated no significant correlation between binocular distance visual acuity and reading acuity (p = .64, r^2 = 02, CI [–.59, .40]) or critical print size (p = .78, r^2 = .006, CI [–.57, .45]) (Figure 2). The participants within group-mild, with the highest level of visual acuity, also demonstrated no significant correlation between distance visual acuity and reading acuity (p = .82, r^2 = .005, CI [–.48, .58]) or critical print size (p = .43, r^2 = .05, CI [–.34, .68]) (Figure 4).

Participants in group-moderate demonstrated a significant correlation of distance visual acuity to reading acuity ($p < .001$, r^2 = .58, CI [.44, .91]) and critical print size (p = .03, r^2 = .27, CI [.05, .80]). See Figure 3 and Table 2. Significant correlations were demonstrated between reading acuity and critical print size in group-severe and group-moderate ($p < .001$/p = .04). There was non-correlation between reading acuity and critical print size in group-mild (p = .06).

Pathology and reading performance

The relationship between distance visual acuity and reading prints size requirements was analysed based on pathology (see Table 3). There was a significant correlation between visual acuity and reading acuity and critical print size in the students with retinal dystrophies ($p < .001$) and optic nerve disorders (p = .05/p = .01).

Within visual acuity groups, group-moderate (n = 17), which was comprised predominantly of individuals with an inherited retinal dystrophy (n = 10), there was a significant correlation between distance visual acuity and reading acuity (p = .008, r^2 = .61, CI [.30, .95]) but not critical print size

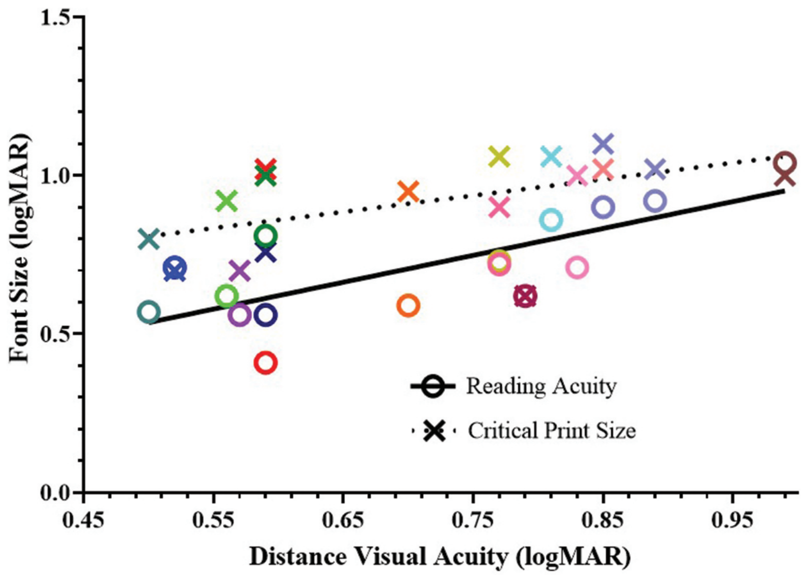

Figure 3. Relationship between reading acuity (circles), critical print size (crosses) and distance visual acuity for n = 17 subjects in Group-moderate. Each colour represents an individual subject. Significant correlations were found in the acuity range 0.50-0.99 logMAR for minimum reading acuity ($p < .001$) or critical print size ($p < .03$). With regression lines for reading acuity (solid line) and critical print size (dotted line).

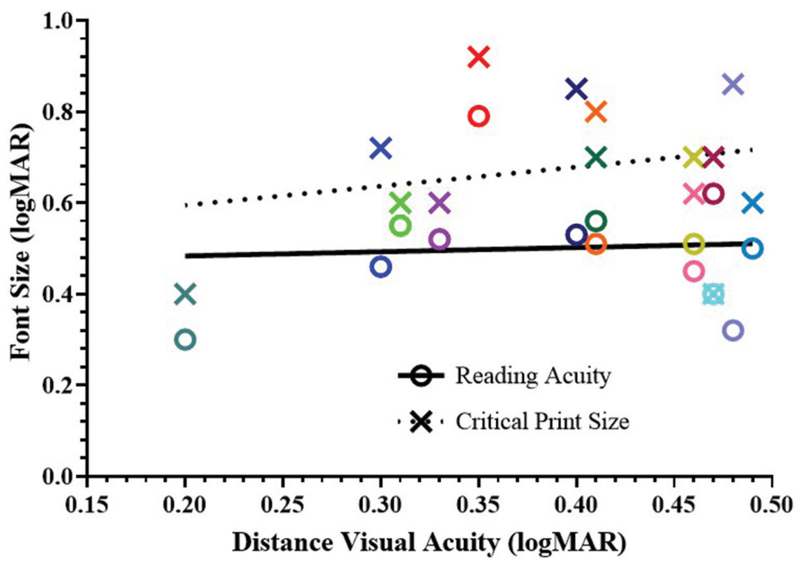

Figure 4. Relationship between reading acuity (circles), critical print size (crosses) and distance visual acuity for n = 14 subjects in Group-mild. Each colour represents an individual subject. No significant correlations were found in the acuity range 0.20-0.49 LogMAR for minimum reading acuity (p = .82) or critical print size (p = .43). With regression lines for reading acuity (solid line) and critical print size (dotted line).

Table 2. Correlation coefficients and significance levels for distance and near measures of acuity and reading. Significant correlations between distance visual acuity and reading performance for group-moderate (moderate vision impairment) only.

	Group-severe	Group-moderate	Group-mild
Distance Visual Acuity and Reading Acuity	$r^2 = .02$ *p* = .64	$r^2 = .58$ *p* < .001	$r^2 = .006$ *p* = .82
Distance Visual Acuity and Critical Print Size	$r^2 = .006$ *p* = .78	$r^2 = .27$ *p* = .03	$r^2 = .05$ *p* = .43

Table 3. Correlation coefficients and significance levels for distance and near measures of acuity and reading based on pathology. Significant correlations between distance visual acuity and reading performance for optic nerve disorders and retinal dystrophies.

	Optic Nerve disorders (*n* = 7)	Albinism (*n* = 13)	Retinal Dystrophies (*n* = 16)
Distance Visual Acuity and Reading Acuity	$r^2 = .58$ *p* = .05	$r^2 = .01$ *p* = .50	$r^2 = .86$ *p* < .001
Distance Visual Acuity and Critical Print Size	$r^2 = .45$ *p* = .01	$r^2 = .21$ *p* = .11	$r^2 = .65$ *p* < .001

($p = .07$, $r^2 = .35$, CI [−.07, .89]) of the individuals with an inherited retinal dystrophy.

In contrast, for group-mild ($n = 14$), which was comprised predominantly of individuals with albinism ($n = 9$), there were no significant correlations between distance visual acuity and reading acuity ($p = .84$, $r^2 = .006$, CI [−.71, .62]) or critical print size ($p = .99$, $r^2 < .001$, CI [−.67, .67]) of individuals with albinism. Group-severe contained a large variation of pathologies and so no direct comparisons could be made between acuity measures and the main pathology.

Discussion

The main findings of this study were no significant correlations between binocular distance visual acuity and reading acuity or critical print size ($p > .47$) for children whose vision impairment is classified as being mild or severe. Therefore, distance visual acuity is not a good predictor of reading ability for children whose distance acuity lies between the ranges of 1.00–1.52 logMAR (group-severe) and 0.20–0.49 logMAR (group-mild). Within group-severe, a non-significant relationship was not unexpected given the lower levels of distance visual acuity for this group. For these individuals, it is important to evaluate their reading font size to determine the optimum accessibility materials for learning. While some of these participants can adequately access print materials in enlarged format, this study indicated that due to the variation in print sizes that are read, some students with similar visual acuities may require a larger font size and therefore a more efficient way to access learning materials in the classroom.

For group-mild individuals, the findings also support a lack of correlation between distance acuity and reading performance and may also require the reading performance measures to be used as a more reliable indicator of classroom performance for reading tasks, despite their 'relatively' good distance acuity.

In contrast, group-moderate participants, with moderate vision impairment, did show a significant correlation between binocular distance visual acuity measures and font size requirements for reading (critical print size $p = .03$ and reading acuity $p < .001$). The reasons for this are uncertain given that between the groups there was no significant differences in nystagmus, age, sex, or academic year levels.

One possible explanation may be that in the group with moderate vision impairment, the participants still maintained adequate oculomotor control and functional visual field, so that distance and near acuity measures were still correlated. These findings suggest that the underlying pathology may be an important factor that influences reading performance, and that reading performance may be more related to the extent of oculomotor control (nystagmus), the functional field of vision, room luminance and the amount of glare. For example, the group with mild vision impairment was dominated by children with albinism (63%) compared to group with a severe (13%) and moderate (18%) vision impairment, whose visual performance would be more likely to be affected by glare and their oculomotor control.

Previous studies have shown that albinism is a contributing factor in decreased reading performance and is thought to be due to nystagmus and foveal hypoplasia with consequent reductions in oculomotor control and susceptibility to glare.[34,35] Although there were no significant group differences between children with and without nystagmus, the severity of the nystagmus was not assessed and may have increased with high room luminance and/or stress during testing,[36] thus negatively impacting reading performance.

Variations observed between groups therefore may be due to interactions of additional factors that can affect reading ability, such as convergence ability, crowding intensity, scanning ability, contrast sensitivity and the extent of the functional field of vision that have all been implicated in reading ability,[21,37,38] These findings suggest that a single measure of distance or near acuity cannot accurately predict the reading performance of every individual child and therefore an assessment of functional reading ability should be a part of the clinical assessment for children with a vision impairment. This would help guide educators to ensure the optimal print size was used to maximise reading speed without a loss of comprehension.

Previous studies have found that reading speed is slower in children with a vision impairment[18–24]; however, this study has also demonstrated that font size requirements are variable and cannot be predicted from standard measures of distance acuity. It highlights the importance of determining critical print size for these individuals, which is the optimal font size that can be read at maximum reading speed. Lighting and glare levels also play a large factor in visual performance, particularly in people with low vision, and a recent case report has highlighted that for a child with a cone dystrophy, reading speed can be improved by reversing the polarity to white text on a black background on electronic displays.[39]

The visual performance of a student in a classroom may be dramatically changed by lighting levels, which can reduce the symptoms of visual fatigue.[40] A student with cone dystrophy or albinism may be negatively impacted by a bright well-lit classroom, as opposed to a student with optic nerve hypoplasia who may need extra light to help differentiate detail. This difference in visual ability, dependent on pathology, may have contributed to the variation in reading results obtained within the groups – as luminance levels can impact reading ability and should also be considered when determining the optimal conditions for a student to read in the classroom.

Therefore, to better classify children according to their vision impairment it is recommended that several factors be considered when evaluating students for support within a classroom, such as their underlying pathology, luminance, contrast of the text, their functional visual field and ocular motor control. By adopting an integrated approach, children with a vision impairment would be better supported in the classroom by ensuring font was at least as large as the critical print size. Contrast (polarity) and room luminance should be optimal, so that visual fatigue and an inability to engage with learning materials appropriately is avoided.

Visual fatigue can be a significant issue for students with low vision, particularly at the end of a school day, which can impact self-esteem and quality of life.[1,40] Strategies that may help to reduce the impact of visual fatigue, such as increasing working distance, regular breaks from visually demanding tasks, encouraging an increase in outdoor play and the use of adaptive technology, may help the child perform more comfortably within the classroom. The use of relaxation techniques to cope with visual fatigue, such a listening to music and napping, may also provide additional methods to support these children.[40] The use of electronic devices that can easily enlarge font to a comfortable size and change contrast or reverse the polarity of text to white on black, can help to improve accessibility to reading materials.

These findings have highlighted that distance visual acuity does not always correlate with the optimal print size requirements and depends upon, in part, the cause of the underlying vision impairment. Thus, the standard clinical measure of distance visual acuity may not always be adequate to determine the font size requirements for children with a vision impairment. Additional measures of near reading ability could assist educators to provide appropriate modifications to text size and contrast to fully support the child.

Considering the range of other factors that affect reading performance, such as pathology, contrast sensitivity, crowding intensity, scanning ability, impact of lighting levels and the presence of nystagmus, is important to optimise environmental conditions so that a student can work in a classroom at their optimum capacity. Further work will be needed to determine whether educational outcomes can be improved by adopting a more individual and holistic approach to assess reading performance in children with vision impairment. Investigating print size requirements in adults with a vision impairment resulting from glaucoma or macular degeneration would also be beneficial to help adults optimise their work productivity and improve their quality of life.

Acknowledgements

The authors would like to thank the students and families of the South Australian School and Services for Vision Impaired, and teachers, for their assistance.

Disclosure statement

No potential conflict of interest was reported by the author(s).

ORCID

Lynne Loh http://orcid.org/0000-0002-1357-9395
Mallika Prem-Senthil http://orcid.org/0000-0001-6560-5594
Paul A Constable http://orcid.org/0000-0002-3994-1700

References

1. Decarlo DK, McGwin G Jr, Bixler ML et al. Impact of paediatric vision impairment on daily life: results of focus groups. Optom Vis Sci 2012; 89: 1409–1416. doi:10.1097/OPX.0b013e318264f1dc.
2. Solebo AL, Teoh L, Rahi J. Epidemiology of blindness in children. Arch Dis Child 2017; 102: 853–857. [published correction appears in Arch Dis Child 2017; 102: 995]. doi:10.1136/archdischild-2016-310532.
3. Gilbert C, Foster A. Childhood blindness in the context of VISION 2020 - the right to sight. Bull World Health Organ 2001; 79: 227–232.
4. Chong C, McGhee CNJ, Dai SH. Causes of childhood low vision and blindness in New Zealand. Clin Exp Ophthalmol 2019; 47: 165–170. doi:10.1111/ceo.13443.
5. Rahi JS, Cable N, British Childhood Visual Impairment Study Group. Severe visual impairment and blindness in children in the UK. Lancet 2003; 362: 1359–1365. doi:10.1016/S0140-6736(03)14631-4.
6. Mitry D, Bunce C, Wormald R et al. Causes of certifications for severe sight impairment (blind) and sight impairment (partial sight) in children in England and Wales. Br J Ophthalmol 2013; 97: 1431–1436. doi:10.1136/bjophthalmol-2013-303578.
7. de Verdier K, Ulla E, Löfgren S et al. Children with blindness - major causes, developmental outcomes and implications for habilitation and educational support: a two-decade, Swedish population-based study. Acta Ophthalmol 2018; 96: 295–300. doi:10.1111/aos.13631.
8. Shirley K, Chamney S, Satkurunathan P et al. Medscape. Impact of healthcare strategies on patterns of paediatric sight impairment in a developed population: 1984-2011. Eye (Lond) 2017; 31: 1537–1545. doi:10.1038/eye.2017.206.
9. Gilbert CE, Anderton L, Dandona L et al. Prevalence of visual impairment in children: a review of available data. Ophthalmic Epidemiol 1999; 6: 73–82. doi:10.1076/opep.6.1.73.1571.
10. World Health Organization. Blindness and vision impairment prevention: priority eye diseases. Childhood blindness. [accessed 2022 Feb 23]. https://www.who.int/news-room/fact-sheets/detail/blindness-and-visual-impairment.
11. Anstice NS, Thompson B. The measurement of visual acuity in children: an evidence-based update. Clin Exp Optom 2014; 97: 3–11. doi:10.1111/cxo.12086.
12. McGraw PV, Winn B, Gray LS et al. Improving the reliability of visual acuity measures in young children. Ophthalmic Physiol Opt 2000; 20: 173–184. doi:10.1046/j.1475-1313.2000.00497.x.
13. Do B, Lynch P, Macris EM et al. Systematic review and meta-analysis of the association of Autism Spectrum Disorder in visually or hearing-impaired children. Ophthalmic Physiol Opt 2017; 37: 212–224. doi:10.1111/opo.12350.
14. Giacomelli G, Volpe R, Virgili G et al. Contrast reduction and reading: assessment and reliability with the Reading Explorer test. Eur J Ophthalmol 2010; 20: 389–396. doi:10.1177/112067211002000220.
15. Butler SR, Marsh HW, Sheppard MJ et al. Seven-year longitudinal study of the early prediction of reading achievement. J Edu Psychol 1985; 77: 349–361. doi:10.1037/0022-0663.77.3.349.
16. Stevenson HW, Newman RS. Long-term prediction of achievement and attitudes in mathematics and reading. Child Dev 1986; 57: 646–659. doi:10.2307/1130343.
17. Narayanasamy S, Vincent SJ, Sampson GP et al. Visual demands in modern Australian primary school classrooms. Clin Exp Optom 2016; 99: 233–240. doi:10.1111/cxo.12365.
18. Corn AL, Wall RS, Jose RT et al. An initial study of reading and comprehension rates for students who received optical devices. J Vis Impair Blind 2002; 96: 322–334. doi:10.1177/0145482X0209600504.

19. Douglas G, Grimley M, McLinden M et al. Reading errors made by children with low vision. Ophthalmic Physiol Opt 2004; 24: 319–322. doi:10.1111/j.1475-1313.2004.00204.x.
20. Lueck AH, Bailey IL, Greer RB et al. Exploring print-size requirements and reading for students with low vision. J Vis Impair Blind 2003; 97: 335–354. doi:10.1177/0145482X0309700603.
21. Huurneman B, Boonstra FN, Goossens J. Perceptual learning in children with infantile nystagmus: effects on reading performance. Invest Ophthalmol Visual Sci 2016; 57: 4239–4246. doi:10.1167/iovs.16-19556.
22. Lovie-Kitchin JE, Bevan JD, Hein B. Reading performance in children with low vision. Clin Exp Optom 2001; 84: 148–154. doi:10.1111/j.1444-0938.2001.tb04958.x.
23. Bosman AMT, Gompel M, Vervloed MPJ et al. Low vision affects the reading process quantitatively but not qualitatively. J Spec Educ 2006; 39: 208–219. doi:10.1177/00224669060390040201.
24. Gompel M, Van Bon WHJ, Schreuder R. Reading by children with low vision. J Vis Impair Blind 2004; 98: 77–89. doi:10.1177/0145482X0409800208.
25. Toledo CC, Paiva AP, Camilo GB et al. Early detection of visual impairment and its relation to academic performance. Rev Assoc Med Bras 2010; 56: 415–419. doi:10.1590/s0104-42302010000400013.
26. White SLJ, Wood JM, Black AA et al. Vision screening outcomes of Grade 3 children in Australia: differences in academic achievement. Int J Educ Res 2017; 83: 154–159. doi:10.1016/j.ijer.2017.03.004.
27. Legge GE, Ross JA, Isenberg LM et al. Psychophysics of reading. Clinical predictors of low-vision reading speed. Invest Ophthalmol Visual Sci 1992; 33: 677–687.
28. Bach M. The Freiburg Visual Acuity test–automatic measurement of visual acuity. Optom Vis Sci 1996; 73: 49–53. doi:10.1097/00006324-199601000-00008.
29. Schulze-Bonsel K, Feltgen N, Burau H et al. Visual acuities "hand motion" and "counting fingers" can be quantified with the freiburg visual acuity test. Invest Ophthalmol Visual Sci 2006; 47: 1236–1240. doi:10.1167/iovs.05-0981.
30. Tsai L, Thomas E, Tarrant J et al. A comparative clinical evaluation of two visual acuity testing systems: ETDRS vs FrAct. Invest Ophthalmol Vis Sci 2015; 56: 3890.
31. Calabrèse A, To L, He Y et al. Comparing performance on the MNREAD iPad application with the MNREAD acuity chart. J Vis 2018; 18: 8. doi:10.1167/18.1.8.
32. Virgili G, Cordaro C, Bigoni A et al. Reading acuity in children: evaluation and reliability using MNREAD charts. Invest Ophthalmol Visual Sci 2004; 45: 3349–3354. doi:10.1167/iovs.03-1304.
33. Bailey IL, Lueck AH, Greer RB et al. Understanding the relationships between print size and reading in low vision. J Vis Impair Blind 2003; 97: 325–334. doi:10.1177/0145482X0309700602.
34. Merrill K, Hogue K, Downes S et al. Reading acuity in albinism: evaluation with MNREAD charts. J AAPOS 2011; 15: 29–32. doi:10.1016/j.jaapos.2010.12.005.
35. MacDonald JT, Kutzbach BR, Holleschau AM et al. Reading skills in children and adults with albinism: the role of visual impairment. J AAPOS 2012; 49: 184–188. doi:10.3928/01913913-20111101-03.
36. Tkalcevic LA, Abel LA. The effects of increased visual task demand on foveation in congenital nystagmus. Vision Res 2005; 45: 1139–1146. doi:10.1016/j.visres.2004.11.004.
37. Dusek WA, Pierscionek BK, McClelland JF. An evaluation of clinical treatment of convergence insufficiency for children with reading difficulties. BMC Ophthalmol 2011; 11: 21. doi:10.1186/1471-2415-11-21.
38. Falkenberg HK, Rubin GS, Bex PJ. Acuity, crowding, reading and fixation stability. Vision Res 2007; 47: 126–135. doi:10.1016/j.visres.2006.09.014.
39. Loh L, Gatsios A, Prem Senthil M et al. Cone dystrophy, childhood vision impairment and education: are clinical measures of visual function adequate to support a child through education? Clin Exp Optom 2021; 105: 1–4. doi:10.1080/08164622.2021.1971044.
40. Schakel W, Bode C, Elsman EBM et al. The association between visual impairment and fatigue: a systematic review and meta-analysis of observational studies. Ophthalmic Physiol Opt 2019; 39: 399–413. doi:10.1111/opo.12647.