Normative data for the crowded logMAR Kay's pictures vision test in children

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Abstract

Aim: **Crowded logMAR Kay's pictures is a commonly used vision test in children and our aim was to establish the normative uniocular mean, test/re-test and inter-ocular visual acuity data for this test.**
Methods: **This was a prospective study on a visually normal paediatric population aged 3–4 years. Normative vision values were collected using the crowded logMAR Kay's pictures test, from children who passed their primary vision screening check.**
Results: **Mean vision data were collected on 110 participants, test/re-test data for 39 participants and inter-ocular acuity data for 38 participants. The overall mean vision value was 0.108 (95% CI ± 0.012, SD 0.062); clinically this mean equates to 0.100 (6/7.5 Snellen's equivalent). The coefficient of reliability for the test/re-test difference was 0.122; indicating ⩾5 pictures difference was significant. The coefficient of reliability for the inter-ocular difference was 0.133; indicating a ⩾6 pictures difference was significant.**
Conclusion: **Normative vision data have been produced for clinicians using the crowded logMAR Kay's pictures vision test in 3- to 4-year-olds.**

Key words: Crowded Kay's pictures vision test, logMAR (logarithm of the minimum angle of resolution), Normative data

Introduction

It is vital for clinicians to know age-appropriate normal levels of visual acuity for specific vision tests, in order to be able to identify subnormal visual acuity and clinically significant acuity changes. Clinicians now measure visual acuity with greater precision by scoring individual standardised letters or pictures, using logMAR-based tests. The crowded logMAR Kay's pictures test grades vision in participants of an age or ability when they are not familiar with the alphabet, making it a valuable alternative to the Keeler crowded logMAR letter test. Crowded logMAR Kay's pictures logarithmically grades vision in 12 incremental steps of decreasing picture size, from 1.000 (6/60 Snellen's equivalent) to −0.100 (6/4.8 Snellen's equivalent).

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Only a small number of published papers give normative vision data for paediatric logMAR visual acuity tests, in differing age groups. Normative vision data are more prevalent for logMAR letter tests,[1–5] but even less published research defines normal visual acuity ranges in children tested with logMAR picture tests.[2,6] Specifically, research already published on the crowded logMAR Kay's pictures vision test does not identify test/re-test data for a normal paediatric population. The purpose of this study was to reinforce known normative vision data and to rectify gaps in knowledge for test/re-test data, when using the crowded logMAR Kay's pictures vision test in a paediatric population.

Methods

Institutional and local research ethics committee approval was obtained. This research was performed in a primary vision screening setting in two separate stages; the two phases were performed 2 years apart. Phase 1 involved collecting the spread of normative visual acuity levels, while phase 2 collected data on test/re-test values and inter-ocular acuity differences, all using the crowded logMAR Kay's pictures test. Both phases were performed on a visually normal paediatric population, identified from children passing their primary visual screening check. Normative vision data have already been gathered using the Keeler uncrowded logMAR letter test, with the normal visual range identified as −0.200 to 0.200 in 4.9-year-olds.[1] This study uses the +2.00DS and −1.00DS lens test to identify a visually normal paediatric population, without a significant refractive error. These normative uncrowded logMAR letter vision data formed the basis for our assigned 0.150 pass rate when using uncrowded logMAR letters in children aged 3–4 years in our pre-school vision screening programme. The uncrowded letter test was used to establish visual normality and was only tested to 0.150 and no further, purely to determine whether a child passed their primary vision screening assessment. This assigned screening pass is two letters within the published normal upper vision limit of 0.200 for the test. This ensured all children tested have a normal visual acuity of at least 0.150 or better.

The ocular examination carried out on each child was: monocular visual acuity measurement in each eye at 3 m testing distance, cover testing at 1/3 m and 6 m, ocular movement assessment, convergence measurement and 20^Δ prism base-out fusion.

Inclusion criteria were based on our departmental vision screening pass:

- a visually normal population of pre-school children aged 3–4 years;
- scoring 0.150 or better using the Keeler uncrowded logMAR letters, in either eye;
- no constant, intermittent or micro-manifest squint;
- heterophoria $\leqslant 10^{\Delta}$;
- no ocular movement anomaly;
- a normal response to a 20^{Δ} prism base-out fusion test and normal convergence;
- no history of previous eye treatment for refractive error.

The exclusion criteria were:

- children who failed their routine primary vision screening check, with reduced vision in one or both eyes, a manifest squint or an ocular movement abnormality;
- any child unable to perform uncrowded logMAR letter matching or crowded logMAR Kay's pictures;
- any child not present for the re-test up to 2 weeks later;
- any child with any neurological or development abnormality.

For crowded logMAR Kay's pictures testing, the protocol related to exactly how many pictures were correctly identified. Each picture correctly identified was assigned the 0.025 vision score. There are eight different picture symbols, with four pictures presented per visual acuity size, surrounded by a crowding box border. All four pictures on the same line were tested until the participant incorrectly identified two consecutive pictures. When a child was unsure of a picture they were encouraged to guess and key cards were used for matching, if necessary. Visual acuity testing using crowded logMAR Kay's pictures was tested fully to threshold level, in order to obtain normal vision distribution data.

Normative uniocular mean vision data

In phase 1 participants were recruited prospectively from children having a routine pre-school vision screening check at community clinics across Newcastle upon Tyne, within a 2-month period. During this time, a total of 159 children attended pre-school vision screening clinics in this area. Parents received information about the research prior to their child's screening check and time was allocated for the orthoptist to explain the study. Parents were invited to participate and written consent was obtained. The orthoptist performed flip-coin randomisation to establish which vision test was to be performed first: either the Keeler uncrowded logMAR letters or crowded logMAR Kay's pictures. The coin was flipped again to establish which eye was to be tested for uniocular mean vision data with crowded logMAR Kay's pictures. Both eyes were tested with uncrowded logMAR letters to ensure visual normality and only one eye was tested with crowded logMAR Kay's pictures.

The total number of parents who gave consent was 115 from the potential 159; this represents a 72% uptake rate for the study, and such a percentage could be due to the face-to-face nature of recruitment. Regarding the 28% of parents who declined for their child to participate in the study, records were not kept to document their reasons. Of the 115 children whose parents gave consent, 2 failed their vision screening check and 3 were subsequently unable to co-operate with testing; these subjects were excluded. Therefore, 110 individuals entered into the mean visual acuity data collection.

Normative test/re-test and inter-ocular vision data

In phase 2, participants were recruited prospectively from children having a routine pre-school vision screening check in nursery schools across Newcastle upon Tyne, over a 4-month period. The nursery school setting meant children could be seen in school for two separate visits to determine test/re-test vision data on the same eye. Inter-ocular acuity data were also recorded for both eyes on one of those visits. Six nursery schools agreed to take part; the nursery class teacher gave parents an information leaflet and study consent form a few days prior to the orthoptist undertaking the vision screening check.

A four-group randomisation approach was adopted for phase 2, with a sealed envelope system being used to allot equal numbers of individuals to having either their right eye or left eye initially tested with crowded logMAR Kay's pictures, and with either crowded logMAR Kay's pictures or uncrowded logMAR letters being tested first. Once the grouping had been allocated, on the first visit Keeler uncrowded logMAR letters were tested on both eyes to ensure visual normality and fulfilment of the inclusion criteria and one eye was tested with crowded logMAR Kay's pictures. The crowded logMAR Kay's pictures test was then performed again within 2 weeks on the same child, to assess vision repeatability. On this second, re-test visit the crowded logMAR Kay's pictures vision test was performed on both eyes, with the re-test eye being tested first. The orthoptist who originally assessed the child performed the test again. One limitation of this study could be the introduction of examiner bias, as orthoptists were not masked to the previous vision score when assessing test/re-test data.

A total of 163 children were due to receive their pre-school vision screening check across all six nursery schools. The number of parents returning consent forms to the class teacher was 54 out of a potential 163 children; this represents a lower 33% uptake rate, perhaps due to the differing method of consent. Of the 54 children whose parents gave consent for them to enter the study, 9 subsequently failed their primary vision screening check, 4 were absent for the re-test, and 2 withdrew from the study; all these individuals were excluded. Therefore, 39 children entered into the test/re-test data collection and, due to an administrative error, 38 individuals formed the inter-ocular data group. It was unfortunate that low numbers of participants were recruited for test/re-test and inter-ocular data; however, the results still allow identification of the trend of these normative data.
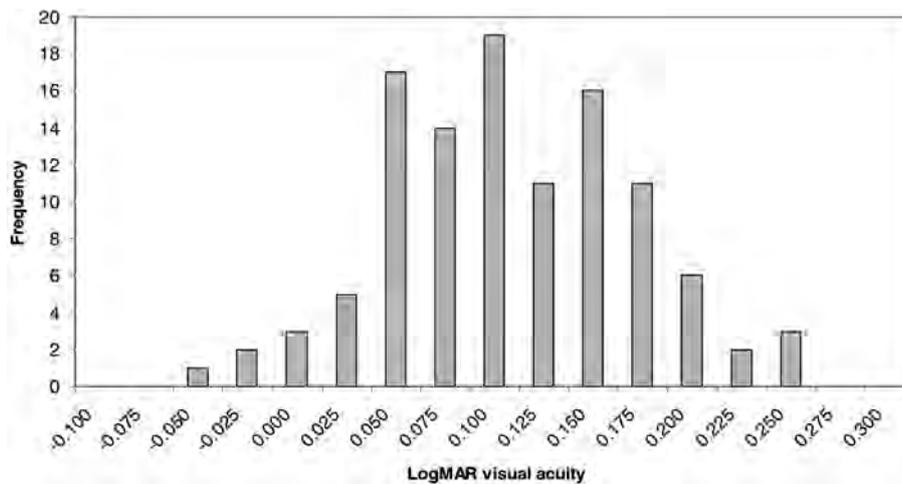
Fig. 1. Frequency histogram for logMAR visual acuity scores using crowded Kay's pictures, in a visually normal population aged 3–4 years.

Results

Normative uniocular mean vision data

Vision was tested on a total of 110 children (67 male, 43 female), with an average age of 3 years 8 months (range 3 years 5 months to 4 years 3 months). Fig. 1 shows the logMAR visual acuity scores for all participants. The median vision value using crowded logMAR Kay's pictures was 0.100 and the normative mean vision was 0.108 (95% CI ± 0.012, SD 0.062, SE 0.006). This normative uniocular mean vision value for crowded logMAR Kay's pictures clinically equates to 0.100 (6/7.5 Snellen's equivalent). The normal range of vision on crowded logMAR Kay's pictures was calculated using the 95% confidence interval; clinically this equates to 0.075 to 0.125. Our results show 43 participants (39%) achieved a normative visual acuity level exactly within this normal vision range. In the distribution of vision scores, 29 subjects achieved visual acuity levels better than the normative range and 38 participants achieved worse levels of visual acuity outside the normative range. The normative mean vision value did not differ clinically between male and female participants, with a mean vision of 0.103 (SD 0.064) in males and 0.117 (SD 0.059) in females. An independent sample *t*-test for mean vision values revealed no significant difference in the mean between males and females ($p = 0.249$, $t = -1.16$, df $= 94$).

An independent sample *t*-test was also used to calculate whether any significant difference existed in the mean vision value depending on which vision test was performed first. The normative mean vision value where crowded logMAR Kay's pictures was tested first was 0.118 ($n = 52$, SD 0.060) and where uncrowded logMAR letters was tested first was 0.099 ($n = 58$, SD 0.063). The independent sample *t*-test revealed no significant difference in the crowded logMAR Kay's pictures normative mean, regardless of whether the crowded logMAR Kay's pictures was performed first or second ($p = 0.115$, $t = 1.59$, df $= 107$).

Fig. 2 shows the normative uniocular logMAR visual acuity scores for each participant plotted in ascending age order in months. From this graph it is possible to determine whether age has any effect on the actual vision score. The normative mean uniocular vision was calculated for the youngest 55 and the oldest 55 participants, with the means being 0.114 and 0.103 respectively. The mean logMAR crowded Kay's pictures vision value from both the younger group and the older group still clinically equates to 0.100, which is the same vision value as the overall normative mean. This shows there was no difference in the crowded logMAR Kay's pictures normative mean throughout the 3–4 years age span.

Normative test/re-test data

A total of 39 children formed the test/re-test vision data (22 male, 17 female). The average age of the participants was 4 years 2 months (range 3 years 7 months to 4 years 10 months). Fig. 3, a Bland-Altman plot, illustrates the difference between the test and re-test values of the same eye for each participant, against each individual mean. The graph shows the overall mean test/re-test value and upper and lower ×2 standard deviation bars. The overall mean visual acuity difference between test and re-test scores was calculated as 0.063 (SD 0.062; SE 0.010). Statistical analysis using the intra-class correlation coefficient (ICC) establishes the agreement between test and re-test scores on crowded logMAR Kay's pictures in the same child. The ICC determines whether the agreement between the two vision values is better than would be predicted by chance alone. A maximum agreement is closer to 1 and a chance agreement is closer to 0. Using the categories suggested by Landis and Koch,[7] quoted in *Medical Statistics at a Glance*,[8] the guidelines indicate ICC values between 0.6 and 0.8 represent a good agreement and ICC values greater than 0.8 indicate an excellent agreement. The ICC value for our test/re-test data is 0.722.

An assumption could be made that test familiarity could play a part and produce a more favourable vision outcome for the re-test. Overall there is no evidence of a learning curve to testing vision on separate occasions, as children were found to perform worse or better on repeat testing with equal frequency. Eighteen (46%) children
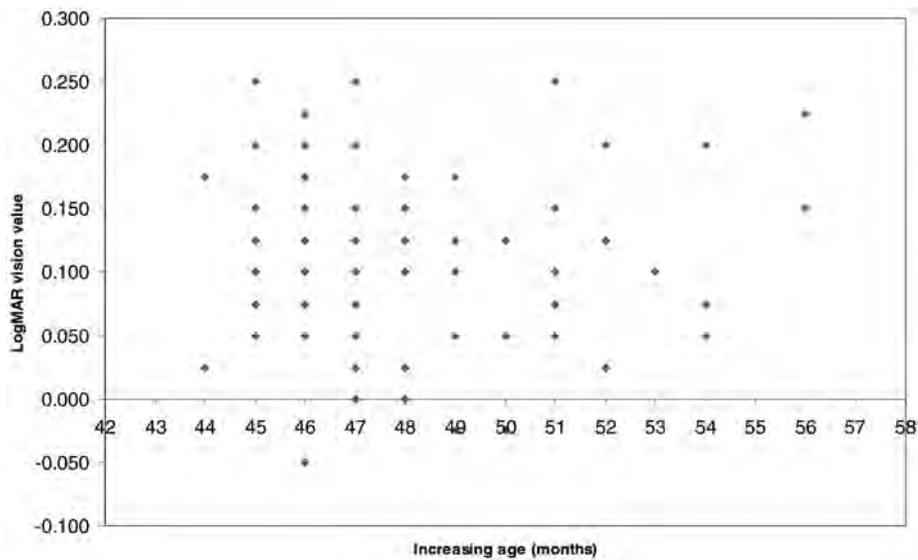
Fig. 2. LogMAR visual acuity scores using crowded Kay's pictures in a visually normal population aged 3–4 years, in ascending age order.
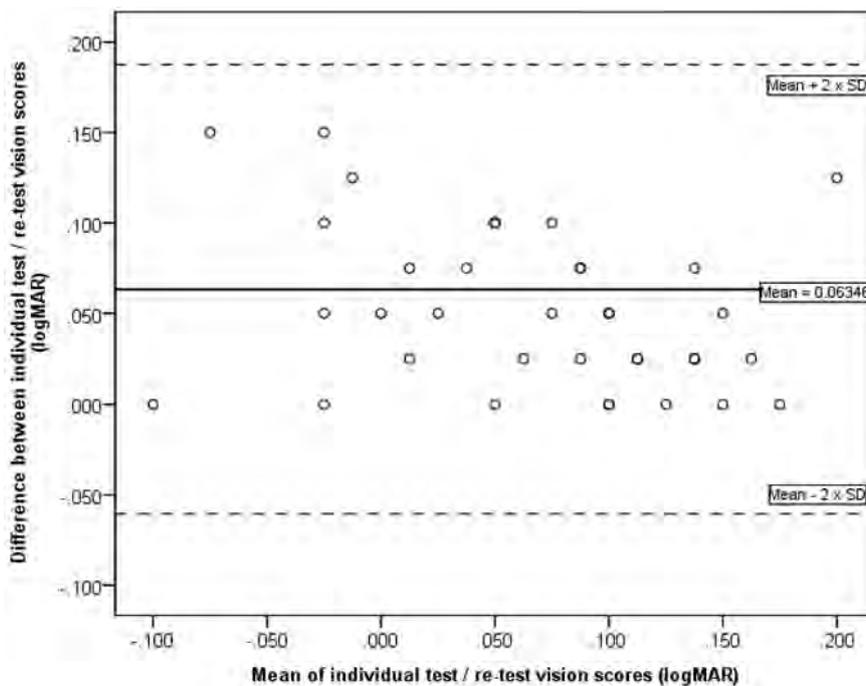

Fig. 3. Bland-Altman graph for the test/re-test logMAR visual acuity scores, using crowded Kay's pictures in a visually normal population aged 3–4 years.

performed slightly worse on the re-test, 17 (44%) children performed slightly better and 4 (10%) children had equal values for the initial test and the re-test.

The coefficient of reliability (COR) can be used on normally distributed data with a continuous scale, as in logMAR vision values. The COR was calculated using the 95% confidence interval at 1.96, multiplied by the standard deviation of the test/re-test difference. To calculate the change in visual acuity for clinical significance, the COR value is rounded up to the next clinically significant optotype value. Statistically, vision results exceeding the COR value are not common and there is a less than 5 in 100 chance that such values are seen in normal subjects. The normal test/re-test COR for crowded logMAR Kay's pictures is 0.122, which rounded up to the next clinical increment means a significant test/re-test difference on crowded logMAR Kay's pictures is ⩾5 pictures.
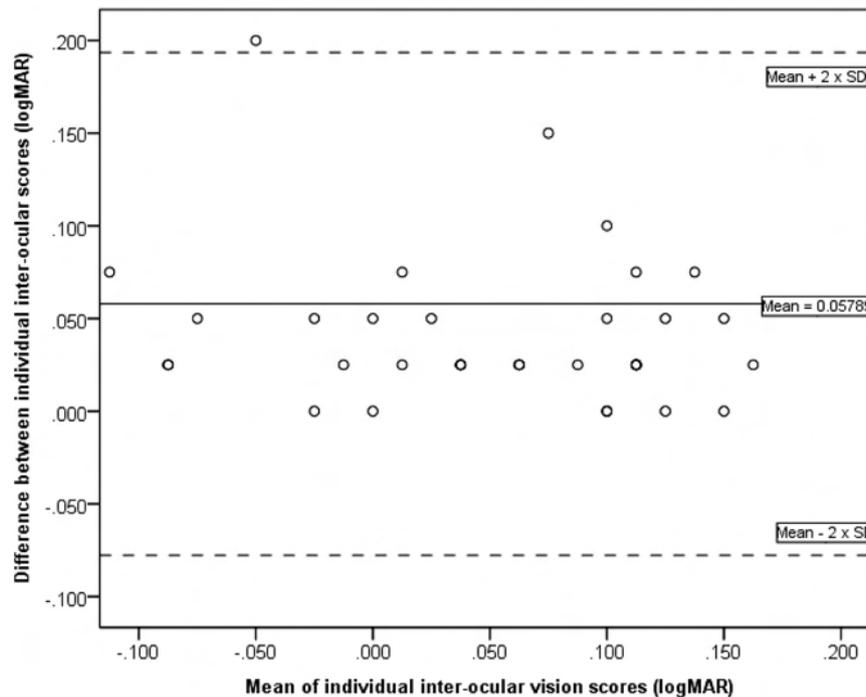
Fig. 4. Bland-Altman graph for the inter-ocular logMAR visual acuity scores, using crowded Kay's pictures in a visually normal population aged 3–4 years.

Normative inter-ocular vision data

A total of 38 children formed the inter-ocular vision group; the average age was 4 years 2 months (range 3 years 7 months to 4 years 10 months). Fig. 4, a Bland-Altman plot, illustrates the difference in inter-ocular visual acuity between the eyes of the same participant, against each individual mean. The graph shows the overall mean difference in inter-ocular acuity and upper and lower $\times 2$ standard deviation bars. The overall mean visual acuity difference between the eyes was calculated as 0.058 (SD 0.068, SE 0.011).

A two-tailed paired *t*-test was calculated for the inter-ocular vision scores ($n = 38$); a *p*-value below 0.05 indicates a statistically significant difference may exist, while a *p*-value equal to or greater than 0.05 infers no difference between groups. The *p*-value itself is limited, however, by the relatively small number of subjects for analysis. The *p*-value for inter-ocular vision scores using crowded logMAR Kay's pictures was 0.145 (mean of first eye tested 0.036, SD 0.094; mean of second eye tested 0.057, SD 0.079). This indicates there is no significant statistical difference between the vision scores in each eye of the same child, but to conclude this reliably a larger cohort would be needed.

Again an assumption can be made about a learning effect for the second eye tested; overall there is no evidence of a learning outcome to inter-ocular testing. The majority, 20 children (53%), actually performed slightly worse for the second eye tested, possibly due to loss of concentration, 12 (31%) performed better and 6 (16%) performed the same for each eye.

The inter-ocular acuity COR for crowded logMAR Kay's pictures was calculated at 0.133 which, rounded to the next clinical increment, means a significant inter-ocular difference on crowded logMAR Kay's pictures is $\geqslant 6$ pictures.

Discussion

Paediatric logMAR vision tests can be divided into two categories: uncrowded or crowded. In crowded tests, contour interaction is induced by the surrounding box border that standardises each optotype to have the same level of identification difficulty. In a comparison of uncrowded versus crowded vision tests, previous research has shown certain uncrowded tests can over-estimate visual acuity when compared with crowded tests. Research by Morad *et al.*[9] revealed logMAR visual acuity scores using the tumbling E test in paediatric participants improved with a line of optotypes compared with a full chart of optotypes, and improved further when testing with single or uncrowded optotypes. Differences in visual acuity also exist in a comparison between crowded logMAR Kay's pictures and single logMAR Kay's pictures, in which mean visual acuity was shown to be poorer using crowded Kay's pictures compared with single Kay's pictures in a group of visually normal children aged 4–6 years.[2] For this reason crowded logMAR vision tests are thought to be a more precise method of quantifying vision and are recommended in the measurement of visual acuity in children. In children with amblyopia, the crowded logMAR Kay's pictures test has been shown to be comparable to crowded logMAR letter testing.[10,11] Therefore it is recommended to test with crowded vision tests as soon

Table 1. Comparison of reported normative data for logMAR crowded Kay's pictures

	Results of current study	logMAR crowded Kay's pictures[2]	logMAR crowded Kay's pictures[15]	logMAR crowded Kay's pictures[6]
Normative mean	0.100 (3–5 years)	−0.100 (4–6 years)	0.100 ($\leqslant$4 years) 0.050 (4–5 years)	0.050 (3.5–4 years)
Normative visual acuity range	0.075 to 0.125			0.000 to 0.100

Table 2. Comparison of reported normative data for logMAR letter testing

	logMAR uncrowded letters[1]	logMAR crowded letters[1]	logMAR crowded letters[2]	logMAR crowded letters[3]	logMAR crowded Sonksen letters[4]
Normative mean	0.018 (4 years)	0.087 (4 years)	0.000 (4–6 years)	0.140 (4 years)	0.050 (4 years)
Normative visual acuity range	−0.200 to 0.200	−0.100 to 0.300		0.000 to 0.300	−0.100 to 0.250

as the child is able to co-operate, especially as the crowding effect has been measured to be more prevalent in younger children aged 4–6 years compared with older children aged 7–9 years.[2] The crowded logMAR Kay's pictures test is therefore ideal in the initial assessment of younger children, before progressing onto crowded logMAR letters.

Contour interaction is one aspect contributing to the crowding phenomenon seen in visual acuity measurement. Contour interaction varies according to the type of optotype presented (e.g. letters, pictures or symbols) and to the separation distance of surrounding contours next to the optotype of fixation. Contour interaction is known to be a feature in multiple-optotype vision testing; this is where adjacent contours interfere with the detection of the actual individual optotype within central fixation.[12] Research by Flom *et al.*,[12,13] Simmers *et al.*[14] and Morad *et al.*[9] revealed that crowding or contour interaction at high contrast is present in visually normal as well as amblyopic individuals, when vision testing is measured to threshold level. Research opinion is somewhat divided regarding whether an artificially higher level of crowding is present in amblyopic individuals compared with a visually normal population. Research by Morad *et al.*[9] identified a more significant crowding effect in subjects with amblyopia but, contrary to this, both Simmers *et al.*[14] and Flom[12] concur there appears to be no difference in the severity of crowding between visually normal participants and amblyopes on high-contrast testing. Normative data from our study could therefore be paralleled to amblyopes seen in clinics, as well as detecting subnormal vision in a normal population in a vision screening programme.

The uncrowded logMAR letter test has been shown to overestimate visual acuity in amblyopic children by 3 optotypes, in comparison with the crowded logMAR Kay's pictures test.[10] There is no direct comparison of these two vision tests in terms of a visually normal population. In our research the Keeler uncrowded logMAR letter test was used only to identify individuals falling within the normal vision category, as normal vision parameters have already been researched.[1] The uncrowded logMAR letter test was not used to define a specific, final vision score. Once the set vision screening 0.150 pass level on uncrowded logMAR letter testing had been achieved, vision was not tested further.

Therefore, our research cannot be used to compare Keeler uncrowded logMAR letters with crowded logMAR Kay's pictures in a visually normal population. Achieving a visual acuity level within normal limits for the uncrowded logMAR letter test was considered sufficient to define normality in this case. The crowded logMAR Kay's pictures vision test was, however, measured to threshold, in order to establish normal vision distribution data.

A further way of ensuring visual normality could have been to use the +2.00DS and −1.00 DS lens test[1] or to refract children, to prove an absence of a significant refractive error. Alternative research into crowded logMAR Kay's pictures has used non-significant refractive error and the absence of any squint or ocular movement anomaly to define visual normality, using a similar age group to our study (42–48 months), with participants also identified through primary vision screening.[6] Normal, borderline and abnormal refractive error parameters were defined and the overall visual acuity score was matched to each of the three refractive error groups. Normal refractive error was defined as −0.25 to +2.75 spherical, with/without $\leqslant$0.75 cylindrical and normal spherical/cylindrical anisometropia of $\leqslant$0.50. In this refraction study,[6] visual acuity for the normal refractive error group was found to be $\leqslant$0.100, which is identical to the median and mean vision value our research identified for this same age group. Table 1 summarises all research on normative vision scores for the crowded logMAR Kay's pictures test. Unpublished figures detailed on the Kay's pictures website[15] similarly obtained a normal vision level of 0.100 in <4-year-olds and 0.050 in 4- to 5-year-olds.

Table 2 summarises normative visual acuity data using logMAR letter tests. One of these studies revealed a mean of 0.018 in Keeler uncrowded and 0.087 in Keeler crowded logMAR letters.[1] Further research into normative visual acuity relating to refractive error in Keeler crowded logMAR letters identified a normal mean monocular acuity of 0.200 in 3-year-olds and 0.140 in 4-year-olds.[3] In this study, average refractive error was defined as <4.00DS of hypermetropia, $\leqslant$1.50DC of cylinder and $\leqslant$1.50DS/DC of anisometropia. In this same paper, subnormal visual acuity was calculated from 95% confidence intervals, whereby $\geqslant$0.400 in 3-year-olds and $\geqslant$0.325 in 4-year-olds were considered

Table 3. Comparison of reported test/re-test data for logMAR vision testing

	Results of current study	logMAR uncrowded letters[1]	logMAR crowded letters[1]
Test/re-test mean difference	0.063 (3–5 years)	0.008 (4 years)	0.004 (4 years)
Coefficient of reliability (COR)	0.100	0.175	0.200
Clinically significant difference	⩾0.125 (5 pictures)	⩾0.200 (8 letters)	⩾0.225 (9 letters)

Table 4. Comparison of reported interocular data for logMAR picture testing

	Results of current study	logMAR crowded Kay's pictures[15]	logMAR crowded Kay's pictures[6]
Inter-ocular difference	0.058 (3–5 years)	0.050 (⩽4 years) 0.025 (4–5 years)	⩽0.050 (3.5–4 years)
Coefficient of reliability (COR)	0.125		
Clinically significant difference	⩾0.150 (6 pictures)		

Table 5. Comparison of reported inter-ocular data for logMAR letter testing

	logMAR uncrowded letters[1]	logMAR crowded letters[1]	logMAR crowded letters[3]	logMAR crowded Sonksen letters[4]
Inter-ocular difference	0.030 (4 years)	0.040 (4 years)	0.030 (4 years)	0.0095 (3–8 years)
Coefficient of reliability (COR)	0.175	0.225	0.125	
Clinically significant difference	⩾0.200 (8 letters)	⩾0.250 (10 letters)	⩾0.150 (6 letters)	

abnormal visual acuity using the crowded logMAR letter test. This research stated a wide range of refractive errors could be associated with a good level of acuity in the 3- to 4-year-old age group.[3] For the Sonksen crowded logMAR letter test, age-related normal vision values have been produced for children aged 2 years 9 months to 8 years. In identifying a similar age group to our study (4-years-olds), the normative mean for the Sonksen letter test would be 0.050.[4]

A literature review did not reveal any published data on test/re-test values in a normal paediatric population for crowded logMAR Kay's pictures. Table 3 shows normative test/re-test data for paediatric letter testing, whereby a clinically significant test/re-test value of ⩾8 letters was identified in Keeler uncrowded logMAR letters and ⩾9 letters in Keeler crowded logMAR letters.[1]

In the refractive crowded logMAR Kay's pictures study[6] the inter-ocular difference between the eyes of the children in the normal refractive error group was found to be 0.050, comparable to our inter-ocular mean difference of 0.058 at the same age. A further un-published study, as highlighted in Table 4, taken from the Kay's pictures website,[15] shows a normative inter-ocular mean difference of 0.050 in <4-year-olds and 0.025 in 4- to 5-year-olds.

Alternative normative research into logMAR letter tests, shown in Table 5, reveals a significant inter-ocular difference is ⩾8 letters in Keeler uncrowded and ⩾10 letters in Keeler crowded logMAR letters.[1] Research using refractive error and visual normality for crowded logMAR letters established an overall normal inter-ocular acuity difference of 0.030 in 3- to 4-year-olds.[3] Taking 95% confidence intervals into account, a sub-normal inter-ocular acuity difference on Keeler crowded logMAR letters was found to be ⩾0.175 (7 optotypes) in 3-year-olds and ⩾0.150 (6 optotypes) in 4-year-olds.[3] A separate paper on crowded logMAR letters found that a significant inter-ocular difference in visually normal children was ⩾0.100 (4 optotypes) in children aged 5 years.[5] For crowded logMAR letters this reveals that the amount of normal difference in visual acuity between the eyes of the same child decreases with age.

Conclusion

Our research shows 0.100 is the median and mean normal visual acuity level for crowded logMAR Kay's pictures in 3- to 4-year-olds. Our test/re-test variation reveals a clinically significant difference is ⩾5 pictures. The inter-ocular data for our research show a clinically significant difference is ⩾6 pictures. Previously our Orthoptic Department used Keeler uncrowded logMAR letter testing in 3- to 4-year-olds for primary vision screening. In line with UK government recommendations this has since changed to using Keeler crowded logMAR letter testing for vision screening in 4- to 5-year-olds. For our current primary vision screening programme, if any child is unable to perform crowded logMAR letters then the crowded logMAR Kay's pictures test is used instead. We have utilised the median and mean vision data from this research to set a level of 0.100 as our primary and secondary vision screening pass for crowded logMAR Kay's pictures.

Thirty-eight of our 110 normative vision subjects (35%) scored ⩾0.150 and therefore had visual acuity scores worse than the upper normative visual acuity limit, with vision ranging from 0.150 to 0.250. Under our local departmental protocols, such children in a primary vision screening environment scoring worse than 0.100 would be referred to a protocol-accredited local optometrist for refraction. Children in secondary vision screening scoring worse than 0.100 would be referred into the hospital eye service for refraction.

Knowing the normative vision data range makes it easier to define subnormal vision and therefore to set fail

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