Accuracy of visual acuity testing in New Zealand primary health care

Nishanthan Ramachandran, Gordon Sanderson, Tui H Bevin, Giles Wynn-Williams

Abstract

Aim To determine if visual acuity is tested reliably in primary health care in New Zealand.

Methods Fifteen to 26 ‘eyes’ from seven participants were tested in the Eye Department of Dunedin Hospital under standardised conditions; and across 17 centres in nine general practices and the Emergency Department of Dunedin Hospital for comparison. Variables including lighting and distance were measured; chart type and centre conditions were recorded.

Results Eleven centres (65%) produced visual acuity scores that were inconsistent with the Eye Department, where 10 (59%) of them produced worse visual acuity scores and one centre (6%) produced better visual acuity score. Ten centres (59%) did not meet New Zealand Transport Agency standards of adequate illumination of greater than 500 lux. Ten centres (59%) failed to have their charts at the specified distance.

Conclusion There were inconsistencies in visual acuity testing in primary health care in Dunedin, New Zealand which may be related to the overall poor compliance with lighting and distance standards. These factors are potentially easily modifiable and their change should lead to improvements in visual acuity measurements.

The general practitioner (GP) or emergency doctor is often the first port of entry into the health system in countries with a primary healthcare model such as New Zealand. The Emergency Department of Dunedin Hospital (ED) was considered a primary healthcare facility for the purposes of this study.

It is estimated that 10% of all patients present to their GP with eye-related conditions, and 2% of ‘Accident and Emergency’ admittance involves the eyes. Furthermore, vision has medicolegal implications in areas such as suitability for surgery, for example in cataracts, and is frequently a reason for withdrawal of driving licences often decreasing independence and quality of life of the person concerned.

Visual acuity is also used as a marker of fitness by the Civil Aviation Authority, Maritime New Zealand, Police, Defence Force and Immigration New Zealand. A reliable and repeatable visual acuity score is increasingly important as vision declines with age and the proportion of older drivers increases.

Visual acuity is a measure of the accuracy of form vision, the ability to discriminate spatially separated visual stimuli. Visual acuity measurement is a general screening tool taught in medical school and used by doctors and allied health professionals.
It can be affected by many variables, including examiner technique, patient variables or physical variables such as lighting, glare, chart type or distance from which the test is conducted. The International Organisation for Standardisation (ISO) provides standardised conditions for visual acuity testing, and the New Zealand Transport Agency (NZTA) provides recommendations for driver testing.

Visual acuity measurement has been shown to be 99% reliable under standardised conditions, and repeatable in a large eye clinic. However, there are to our knowledge, very few studies that have investigated the reliability of visual acuity scores outside a controlled environment in a primary healthcare sector.

These studies have limited generalisability to a New Zealand primary healthcare setting as they differ temporally and geographically and are deficient in relating the effect of various variables to visual acuity scores. Hence, this study aimed to determine the accuracy of visual acuity testing in New Zealand primary health care.

**Methods**

**Study design**—This was a comparative study which used 5 patients from the Dunedin Hospital Eye Department between the ages of 67 and 88, the elderly participants; and two students from University of Otago aged 21, the young participants. Both eyes of all 7 participants were tested for visual acuity in the Eye Department of Dunedin Hospital, general practices and ED. Ethical approval was granted from the Lower South Regional Ethics Committee. Informed consent was obtained from all of the participants, general practices and ED.

**Study sites**—All general practices in Dunedin that were members of Southern Primary Health Organisation (SPHO) were contacted, apart from two which were excluded for not falling within the reasonable driving radius of 30 minutes from Dunedin Hospital. Twenty-eight general practices were contacted between 14 November 2011 and 13 December 2011. Eleven general practices showed interest and nine practices were able to participate within the given time frame of 6th and 20th December 2011. (Five practices were not followed up due to time constraints.) Along with ED there were 10 localities that participated. There were in total 17 visual acuity testing centres as some of the localities had multiple centres. Six general practices and ED had one centre, one general practice had two centres, one three centres and one five centres.

**Study protocol**—The five elderly participants had their right and left eyes tested with and without visual aids, equating to a total of 20 ‘eyes’. The two young participants had their right and left eyes tested: without visual aids, with visual aids plus cataract simulating goggles, and with visual aids; totalling 12 ‘eyes’. (The cataracts simulating goggles were made using sheets of lightly frosted plastic according to standard Eye Department methodology.)

Six of these ‘eyes’ were not tested as they were 6/60 (logMAR 1.0) or below in visual acuity score when tested in the Eye Department. This made a total of 26 ‘eyes’ available for testing. However, due to participant non-attendance, between 15 and 26 ‘eyes’ were tested in each centre, with 10 ‘eyes’ being tested in all centres. (Table 1).

**Table 1. Number of ‘eyes’ tested in each centre**

<table>
<thead>
<tr>
<th>Centre No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of ‘Eyes’</td>
<td>16</td>
<td>18</td>
<td>15</td>
<td>15</td>
<td>24</td>
<td>24</td>
<td>20</td>
<td>24</td>
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<td>26</td>
<td>22</td>
<td>22</td>
<td>20</td>
<td>26</td>
</tr>
</tbody>
</table>

The visual acuity of the seven participants (all 26 ‘eyes’) was first tested in the Eye Department of Dunedin Hospital under standardised conditions (logMAR chart at 4 m with 1700 cd/m² luminance). Participants were then tested in as many of the 17 study centres as their personal commitments allowed. The participant order of testing was randomised and the examiners followed a masked protocol, so they were not aware of the participants’ visual acuity score.
All participants were tested in order of best to worst combination of vision to minimise chart memorisation. Over the 17 centres and the Eye Department there were 12 different types of charts used, and one type of chart was repeated no more than three times.

Information bias was minimised by asking the examiner (doctor or nurse) to administer the test as they would for any other patient. Visual acuity scores were converted to logMAR units in order to achieve standardisation. (Snellen charts were approximated to logMAR units.) Where the participant could not read the top line of the chart at the required distance, this was later converted to logMAR score of 1.0. The logMAR score was adjusted by 0.02 for each letter either read or missed on a particular line.

Lighting and distance variables were measured; chart variables and centre conditions were recorded. Illumination (lux) of externally illuminated charts was measured using an illuminance meter (DSE Model Q-1400 Lux Meter) with the cosine corrected probe that was suspended directly over the 4/8 (6/12) portion of the chart (the critical value for passing class 1 or 6 driver licence as stated by NZTA), in contact with the chart and facing external light source(s). Luminance of internally illuminated charts was measured using the same lux meter at the 4/8 (6/12) chart position, with the probe placed in contact with the chart but facing inwards. Lux readings were converted to absolute luminance (cd/m²) values by using a cross calibration conversion factor, which was acquired by use of calibrated luminance probe (using precision light measurement equipment, RTI Electronics (Sweden) ‘Piranha’ system with light probes LUX 80LX-110404 and MON80MO-110404, calibrated at RTI (Sweden) June 2011), and the lux meter measuring luminance of a range of internally illuminated screens under laboratory conditions at Dunedin Hospital (Medical Physics).

Care was taken to avoid shadowing of the probe during the measurements. The source of light was noted, including the use of window light. The marked distance of the chart was recorded to the nearest 0.1 m using an 8 m tape, as well as the type of chart used (Snellen or logMAR) and the location of the centre.

Box and Whisker plot (non-parametric descriptive graph) was used to find inconsistencies in visual acuity scores between the Eye Department and the centres. Statistical analysis was carried out using statistical software, IBM SPSS.

Results

Eleven of the 17 centres (65%) produced visual acuity scores that were inconsistent with the Eye Department. Visual acuity scores were determined to be inconsistent when the interquartile ranges of the centres did not overlap with the no difference value of 0.00 in analyses with ‘eyes’ attending all centres and all ‘eyes’.

Ten of these 11 centres or 59% of the 17 centres produced worse visual acuity scores and one centre (10) or 6% of the 17 centres produced better scores than the Eye Department. (Figure 1a & 1b)
Figure 1a. Box and whisker plot for ‘eyes’ attending all centres

Footnote: VA = visual acuity. Centre VA of each ‘eye’ was subtracted by the Eye Department VA. There are 10 ‘eyes’ in each box and whisker. Outliers are shown as circle (1.5 × interquartile range) and asterisk (3.0 × interquartile range).
Visual acuity scores for centres 1 and 14 were inconsistent with the Eye Department’s when analysed for ‘eyes’ attending all centres, however, when all ‘eyes’ were included in the analysis, they were consistent. All other centres were uniformly consistent or inconsistent in both analyses.

Light intensity ranged from 160 to 2500 lux (mean of 630 lux) for externally illuminated charts and from 1800 to 4400 cd/m² (mean of 3100 cd/m²) for internally illuminated charts. Ten of the 17 centres (59%) did not meet NZTA standards of greater than 500 lux illumination of the chart. Internally illuminated charts were 15 to 37 times of the recommended lighting of 500 lux equivalence. (This was determined by multiplying luminance scores by \( \pi \times 1/\text{albedo} \), where the charts were assumed to have lambertian surface and the albedo was assumed to be 0.75.) Two of
17 centres had internally illuminated charts with luminance well in excess of the recommended 80 to 320 cd/m² by the ISO.9

The distance ratio (marked distance patient instructed to stand behind divided by specified distance on chart) ranged from 0.8 to 1.5 with a mean of 1.0, where 10 of the 17 centres (59%) had patient distances that were not accurately marked. The centre was considered to be accurately marked if the distance was within +/- 5% of the specified distance. (All centres used direct chart testing.) The Eye Department chart had a distance ratio of 1.0.

Tables 2a and 2b show light intensity and distance ratio respectively in ascending order. A pattern emerged with clustering of centres with worse visual acuity scores around low light intensity. Ordinary room ceiling light was the sole light source of most of these centres, where charts were often not uniformly lit. There was no obvious pattern with distance ratio or with centres stratified by chart type. (Table 2c)

Nine of 17 centres (53%) did not draw their window blinds when conducting the test, providing a potential source of glare.

Furthermore, three centres tested visual acuity in a hallway with multiple doorways. Three of five nurses and two of 12 doctors indicated they had not received sufficient formal training in measuring visual acuity. Three of the 17 centres had 3 m charts. None of the participants complained of deteriorating vision or visual problems over the course of the study.
Tables 2a,b,c. Physical variables in centres

<table>
<thead>
<tr>
<th>Table 2a. Lighting</th>
<th>Table 2b. Distance</th>
<th>Table 2c. Chart type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Centre&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Light Intensity (lux)</td>
<td>Light Source</td>
</tr>
<tr>
<td>5</td>
<td>160</td>
<td>Room Light</td>
</tr>
<tr>
<td>7</td>
<td>160</td>
<td>Room Light</td>
</tr>
<tr>
<td>3</td>
<td>180</td>
<td>Room Light</td>
</tr>
<tr>
<td>12</td>
<td>180</td>
<td>Room Light</td>
</tr>
<tr>
<td>16</td>
<td>190</td>
<td>Room Light</td>
</tr>
<tr>
<td>9</td>
<td>220</td>
<td>Room Light</td>
</tr>
<tr>
<td>6</td>
<td>225</td>
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<td>530</td>
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<td>4</td>
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<td>Room Light</td>
</tr>
<tr>
<td>13</td>
<td>990</td>
<td>Room Light</td>
</tr>
<tr>
<td>10</td>
<td>+ 1800&lt;sup&gt;d&lt;/sup&gt;</td>
<td>Back Light</td>
</tr>
<tr>
<td>11</td>
<td>2200</td>
<td>Spot Light</td>
</tr>
<tr>
<td>17</td>
<td>2500</td>
<td>Spot Light</td>
</tr>
<tr>
<td>1</td>
<td>4400&lt;sup&gt;d&lt;/sup&gt;</td>
<td>Back Light</td>
</tr>
</tbody>
</table>

Footnote: VA = visual acuity.
2a. Centres with worse VA marked with -, better VA marked with + and no difference left blank.
2b. Distance Ratio = Marked distance / Distance specified on chart.
2c. Light source is in addition to ordinary room ceiling light. d. Luminance in cd/m<sup>2</sup>.

Discussion

Visual acuity scores in 65% of the centres were inconsistent, with all but ‘one’ having worse mean visual acuity scores than the Eye Department. Light intensity and distance were highly variable. This is consistent with previous studies.<sup>7,8</sup> Moreover 59% failed to meet NZTA’s standards in light intensity,<sup>10</sup> and 59% failed to have an accurately marked distance for the charts.
Centres were determined to produce inconsistent visual acuity scores with the Eye Department, only when this was shown in both figure 1a and figure 1b. This ensured a conservative method of analysis was used, where all ‘eyes’ were used in support of the ‘eyes’ that attended all centres.

One explanation for variation in light intensity is the absence of recommended lighting in the ‘Royal New Zealand College of General Practitioners’ (RNZCGP) standards. Visual acuity increases with respect to chart luminance, reaching a plateau over the range of 100 to 10,000 cd/m². The recommended value by the ISO and the light intensity of the internally illuminated charts, including the Eye Department, fall within this range. Externally illuminated charts are likely to have a similar relationship.

Space limitation of rooms, misreading recommended distances and inaccurate measurements offer explanations for failure to meet specified chart distances. Centre 10’s better visual acuity scores than the Eye Department is probably due to the chart being placed too close to the participant.

Testing done at a distance other than what the chart is calibrated for will yield inaccurate visual acuity scores, since chart calibration specifies a set distance. (Centre 10 had similar lighting, glare and chart type to the Eye Department.) ISO recommends a minimum viewing distance of 4 m.

Glare has a negligible effect on visual acuity for high contrast charts for patients with no lens opacities. High contrast charts are normally used for visual acuity measurement. However, glare can affect the contrast of optotypes (figures or letters) on the chart, in varying amounts affecting chart consistency.

Optotypes in the chart should be of uniform contrast throughout. Patients with cataracts are less tolerant to charts that do not meet the recommended high contrast ratio, where glare may significantly alter their visual acuity score. Therefore, glare should be minimised by taking adequate measures to have non-reflective charts and closing window blinds.

Although no obvious pattern existed with chart type in this study, logMAR charts have been shown to be more accurate than the traditional Snellen charts. Neuronal processing is a known component of visual acuity, and should be considered into testing where there could be distractions, such as in hallways of busy practices.

Furthermore, despite the small sample size, the proportion of medical professionals indicating not receiving sufficient formal training in measuring visual acuity was of particular concern, as 98% of general practitioners in New Zealand rate the ability of a graduating medical student to perform visual acuity measurements as being important.

The study had the following limitations:

- The small number of participants, multiple measurements from the same eye, coupled with the non-attendance in each centre meant that we were unable to generalise the results of the study to New Zealand, draw further conclusions.
such as the reliability of result in each centre, nor directly relate visual acuity scores to variables.

- Potential selection bias as only 11 of 23 practices (48%) that were followed up were willing to participate.
- It is possible that examiners produced better visual acuity scores than otherwise because the test was in a study situation.
- The use of different examiners may have added to the inconsistencies, although this has shown to have minimal influence on previous studies using standard measurement procedures.\textsuperscript{11,12}

Based on these biases, the proportion of centres that produced worse visual acuity scores in comparison to the Eye Department may have been falsely lowered in this study. In spite of these limitations, however, it was considered that this study provided substantial evidence for a multi-region based study.

The proportion of the population over 65 is increasing in New Zealand; vision declines with age and loss of mobility and independence is a frequent cause for depression in the elderly.\textsuperscript{5}

Inaccurate visual acuity measurement can result in poor grading of suitability for surgery such as cataracts. The influence of the primary or emergency doctor on driver licensing and vision screening is most important; and if doubts exist regarding a patient’s vision, he or she is often referred to an optometrist or an ophthalmologist.

Therefore, it is important that visual acuity is measured accurately to prevent unnecessary referrals, to maintain independence in the elderly, for occupational eligibility and for immigration.

**Conclusion:**

As a preliminary study, we conclude that there are inconsistencies in visual acuity testing in primary health care in Dunedin, New Zealand; which may be related to variable lighting conditions and failure to conform to calibration distances as stated on the charts. These factors are potentially easily modifiable and their change should lead to improvements in visual acuity measurements.

**Recommendations:**

- Specified chart distance should be adhered to by providing a clear mark on the floor for patient positioning. Charts with a specified viewing distance of 4m or more are recommended.\textsuperscript{9}
- An externally illuminated chart should be illuminated to at least 500 lux,\textsuperscript{10} while an internally illuminated chart should have a luminance between 80 cd/m\textsuperscript{2} and 320 cd/m\textsuperscript{2}.\textsuperscript{9}
- Blinds should be drawn on windows and non-reflective charts used to minimise glare.
- Internally illuminated charts are recommended as they provide the best source of lighting; alternatively a spotlight positioned appropriately and taking care to minimise glare can usually meet recommended lighting standards.
• LogMAR charts are recommended over Snellen charts.13,17 High contrast charts should be used,4,6,17 where optotypes do not differ noticeably in contrast and contour.9

• RNZCGP Cornerstone standards should specify lighting standards.

Competing interests: Nil.

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