

## Do the Pelli-Robson and Test Chart 2000 Xpert demonstrate comparable contrast sensitivity results?

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### Abstract

**Aim:** To establish whether the contrast sensitivity threshold obtained with the computerised Test Chart 2000 Xpert is comparable with the printed Pelli-Robson chart.

**Methods:** Healthy volunteers from a student population were recruited. The inclusion criteria included: monocular visual acuity of at least 0.2 logMAR, no history of any ocular abnormalities and amblyopia, no sign of any manifest strabismus and a Frisby stereo-acuity threshold of at least 85 seconds of arc. Visual acuity was assessed at 1 m to allow the contrast sensitivity to be directly comparable. The results were statistically analysed using a two-factor ANOVA and a paired *t*-test.

**Results:** Twenty participants (7 male, 13 female) were recruited with a mean age of  $20.9 \pm 6.0$  years. The average visual acuity tested at 1 m was  $-0.05 \pm 0.12$  logMAR for the right eye,  $-0.07 \pm 0.11$  logMAR for the left eye and  $-0.11 \pm 0.12$  logMAR tested binocularly. The average contrast sensitivity using the Pelli-Robson chart was  $1.63 \pm 0.02$  log unit for the right eye,  $1.62 \pm 0.04$  log unit for the left eye and  $1.70 \pm 0.05$  log unit when tested with both eyes open. The average contrast sensitivity using the computerised Test Chart 2000 Xpert was  $1.84 \pm 0.13$  log unit for the right eye,  $1.85 \pm 0.15$  log unit for the left eye and  $2.02 \pm 0.20$  log unit when tested with both eyes open. A significant difference was found in contrast sensitivity scores between the two tests ( $p < 0.001$ , paired *t*-tests). The Test Chart 2000 Xpert also consistently gave higher contrast sensitivity scores when compared with the Pelli-Robson. Weak correlations were noted between visual acuity and both contrast sensitivity tests testing right eye, left eye and with both eyes open, with Pearson's correlation coefficient values ranging between  $r = 0.40$  and  $r = 0.11$ .

**Conclusion:** The study was carried out to determine whether the contrast sensitivity threshold values obtained with the computerised Test Chart 2000 Xpert are comparable with those obtained with the Pelli-Robson chart. A significant difference was found between the scores from the two tests and the Test Chart 2000 Xpert consistently generated a

higher contrast sensitivity threshold. This study did not assess test–retest variability. It is acknowledged that further studies with a larger sample size and repeat testing on two visits are required to assess repeatability.

**Key words:** Contrast sensitivity, Pelli-Robson, Test Chart 2000 Xpert

### Introduction

Testing of visual acuity permits assessment of visual performance at high spatial frequencies and maximum contrast. Contrast sensitivity, however, which is defined as the ability of the visual system to distinguish between an object and its background, allows the measure of visual function at low contrast and varying spatial frequencies.<sup>1</sup> Assessment of contrast sensitivity has been found to be a better predictor of an individual's quality of vision and visual performance than visual acuity.<sup>2–4</sup> Thus contrast sensitivity testing is recommended in the assessment of visual impairment and for use in low vision clinics.<sup>5</sup> Furthermore, studies have shown that contrast sensitivity assessment can aid in the detection and evaluation of the progression of ocular diseases such as optic neuritis,<sup>6,7</sup> infantile and age-related cataract,<sup>8–11</sup> glaucoma,<sup>9,10</sup> age-related macular degeneration,<sup>11</sup> stroke patients,<sup>12</sup> thyroid-associated ophthalmopathy<sup>13</sup> and amblyopia.<sup>14</sup> A study by the Cryotherapy for Retinopathy of Prematurity Cooperative Group demonstrated the effect of cryotherapy on visual functions. The study showed that with or without cryotherapy patients with severe retinopathy of prematurity (ROP) showed poorer contrast sensitivity than preterm children who did not develop ROP.<sup>15</sup>

The Pelli-Robson chart is one of the most commonly used clinical contrast sensitivity tests. Its design comprises eight rows of letters with six identical-sized letters on each row. The letters are grouped into triplets so each group of three letters has the same contrast and two sets of triplets are presented per line. The contrast decreases from 100% to 0.5% across and down the chart. The change in contrast between successive triplets is 0.15 log units (41%) and ranges between 0.00 and 2.25 log contrast sensitivity (CS).

High test–retest repeatability has been demonstrated using the Pelli-Robson chart in normal and low vision individuals<sup>1,16,17</sup> and thus it has been considered the gold standard in studies evaluating newly designed contrast sensitivity tests.<sup>18–20</sup>

Computer-based visual acuity charts have become increasingly popular for clinical use. A number of studies have validated computerised visual acuity tests against the ETDRS or Bailey-Lovie charts.<sup>21,22</sup> These studies found that visual acuity scores obtained with the computerised charts agreed well with the standard charts. The computerised charts produced similar or even higher test-retest repeatability. The advances in computerised technology allow new opportunities for eye care professionals to use computerised software packages to perform ocular examinations, and to store and document patient data. The Pelli-Robson contrast sensitivity test is the most frequently used test in clinic. To our knowledge only one study has compared the computerised equivalent Pelli-Robson tests in a group of patients and a small group of normals.<sup>20</sup> This study compared the standard Pelli-Robson chart against the computerised equivalent using the more recent Thomson Test Chart 2000 Xpert software in a group of normals. The aim was to determine whether the results from the Pelli-Robson test and Test Chart 2000 Xpert are comparable.

## Methods

### Participants

A group of healthy volunteers was recruited from the University of Sheffield comprising both orthoptics and non-orthoptics students. University departmental ethics approval was sought and obtained for the study. All participants were given an information sheet and verbal explanation of the experimental procedures. Written consent was obtained from each participant before commencing the study. Inclusion criteria included visual acuity of at least 0.2 logMAR monocularly and binocularly on the ETDRS chart at 6 m and stereo-acuity of 85 seconds of arc or better using the Frisby stereo-acuity test. Participants were excluded if they had any ocular diseases, history of amblyopia or presence of manifest strabismus.

### Design of the experiment

This was a prospective repeated measures study designed to assess the comparability of the Pelli-Robson chart and Test Chart Xpert 2000 software tested at 1 metre (m). Visual acuity was also measured at 1 m so the relationship between visual acuity and contrast sensitivity scores could be directly compared. A counterbalance method was used to ensure the procedure was randomised and to minimise bias induced by order effect.

### Procedure

The visual acuity was assessed using the near ETDRS chart at 1 m. This chart is usually performed at 40 cm. Therefore the visual acuity scores measured at 1 m were recalculated and converted to allow for the increased testing distance. The formula suggested that by subtracting 0.4 logMAR from the visual acuity score it would be appropriately converted for 1 m testing. Furthermore, visual acuity was measured both monocularly and binocularly as this is how contrast sensitivity was measured.

Using the counterbalancing method the order of the contrast sensitivity tests and eye(s) tested (right eye, left eye and binocularly) were randomised. The Pelli-Robson chart was mounted on the wall, which required the participants to be standing to allow the chart to be at eye level. All the participants were encouraged not to lean forward, so as to keep the appropriate testing distance, and were observed by the examiner. To allow a consistent testing distance a marker was set at 1 m; if the participant leant over the line then the results were not valid and the participant was asked to repeat the test. The participants were asked to read the charts from top to bottom and were encouraged to guess where appropriate.

The Thomson Test Chart 2000 Xpert software generated the contrast sensitivity on a liquid-crystal display (LCD) screen through a standard VGA connection. It was mounted at the same height as the Pelli-Robson chart and calibrated to be used at 1 m. As with the Pelli-Robson chart, all participants were encouraged not to lean forward, to read from the top of the chart and to guess where appropriate. To ensure screen luminance was constant, the screen was switched on before the experimental procedure was started and set at its maximum luminance ( $120 \text{ cd m}^{-2}$ ). The letters on the Test Chart 2000 Xpert were randomised for each testing condition (right eye, left eye and binocularly) to prevent the participants from memorising the letters.

The letter-by-letter scoring method was employed for both contrast sensitivity tests, whereby each letter correctly identified was given a score of 0.05 log unit.<sup>1</sup> The luminance of the room was kept consistent for each participant to avoid such confounding variables affecting the results. To ensure the room luminance was consistent whilst using both the Pelli-Robson and Test Chart 2000 Xpert the lights were left on for a period of 20 minutes to allow the room to be fully lit.

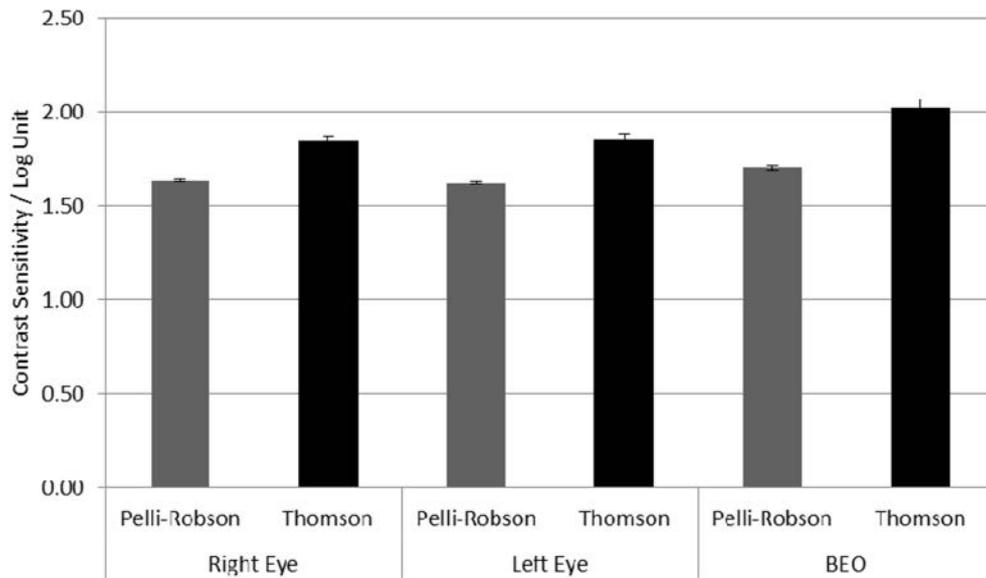
### Statistical analysis

A two-factor ANOVA was performed to compare the Pelli-Robson and Test Chart 2000 Xpert scores. The relationship between visual acuity and the contrast sensitivity scores was examined using scatter plots with significance values set at  $p > 0.05$ . A *t*-test was also done to assess whether there was any statistically significant difference between contrast sensitivity and visual acuity.

## Results

A total of 20 healthy volunteers (7 male, 13 female) with a mean age of  $20.9 \pm 6.0$  years (range 19–25 years) completed the study. Within the sample 4 wore spectacle lenses, 6 contact lenses and 10 were emmetropic. Fig. 1 illustrates the mean contrast sensitivity scores for both the Pelli-Robson and Test Chart 2000 Xpert.

The mean, standard deviation and range of the visual acuity and Pelli-Robson contrast sensitivity are shown in Table 1. On analysis there was no statistically significant difference between the right and left visual acuity data ( $p = 0.77$ ) using a paired *t*-test. Furthermore, no



**Fig. 1.** The average contrast sensitivity scores of the right eye, left eye and binocular data (BEO) using the Pelli-Robson chart and Test Chart 2000 Xpert.

**Table 1.** The mean, standard deviation and range of the visual acuity and contrast sensitivity scores using the Pelli-Robson chart and Test Chart 2000 Xpert at 1 m testing distance

	Visual acuity (logMAR)			Pelli-Robson (log unit)			Test Chart 2000 Xpert (log unit)		
	Right eye	Left eye	BEO	Right eye	Left eye	BEO	Right eye	Left eye	BEO
Mean	-0.05	-0.07	-0.11	1.63	1.62	1.70	1.84	1.85	2.02
SD	0.12	0.11	0.12	0.02	0.04	0.05	0.13	0.15	0.20
Range	0.18 – (-0.26)	0.16 – (-0.24)	0.10 – (-0.30)	1.65–1.60	1.65–1.55	1.85–1.65	2.10–1.65	2.25–1.65	2.25–1.75

BEO, both eyes open.

significant difference was found comparing right visual acuity with visual acuity tested binocularly ( $p = 0.07$ ) or left visual acuity compared with that tested binocularly ( $p = 0.10$ ).

The mean, standard deviation and range of the contrast sensitivity using the Test Chart 2000 Xpert are also shown in Table 1. A significant difference in contrast sensitivity scores obtained with right eye, left eye or when tested with both eyes open was found ( $F_{(2,38)} = 47.6, p < 0.0001$ ). The contrast sensitivity test performed also had a significant impact on the scores ( $F_{(1,19)} = 78.0, p < 0.0001$ ). Examining the interaction between the eye and test performed again showed a significant difference ( $F_{(2,38)} = 10.2, p = 0.0003$ ). A significant difference was also found in contrast sensitivity scores between the two tests for right eye, left eye and testing with both eyes open ( $p < 0.0001$ , paired  $t$ -test). Monocular versus binocular scores for both the Pelli-Robson chart and Test Chart 2000 Xpert were significantly different ( $p < 0.0001$ ). However, comparison of right and left eye data was not significantly different for the Pelli-Robson chart ( $p = 0.10$ ) or the Test Chart 2000 Xpert ( $p = 0.49$ ).

The relationship between visual acuity and contrast sensitivity measured using the Pelli-Robson and Test Chart 2000 Xpert was examined (Fig. 2). Weak correlations were noted between visual acuity and both

contrast sensitivity tests, with correlation coefficient values ranging between  $r = 0.40$  and  $r = 0.11$ . It can, however, be seen from Fig. 2 that the contrast sensitivity scores obtained using the Test Chart 2000 Xpert are consistently higher and appear more variable than those from the Pelli-Robson chart for right eye, left eye and testing with both eyes open.

### Discussion

In this study the contrast sensitivity results of the Pelli-Robson chart and the computerised Test Chart 2000 Xpert were compared. A significant difference between the contrast sensitivity scores was found for the two tests. The contrast sensitivity scores were consistently higher for all participants with the Test Chart 2000 Xpert. This shows that the Test Chart 2000 Xpert is not directly comparable to the Pelli-Robson chart.

The results concur with Thayaparan *et al.*'s<sup>20</sup> study findings that the computerised Test Chart 2000 did not agree well with the Pelli-Robson chart. However, they did not report that the Pelli-Robson scores were consistently lower than those obtained with the Test Chart 2000. Like Thayaparan *et al.*<sup>20</sup> this study presented the letters for the Test Chart 2000 Xpert test on an LCD screen. They argued an LCD screen may present low-contrast letters at a suboptimal level and

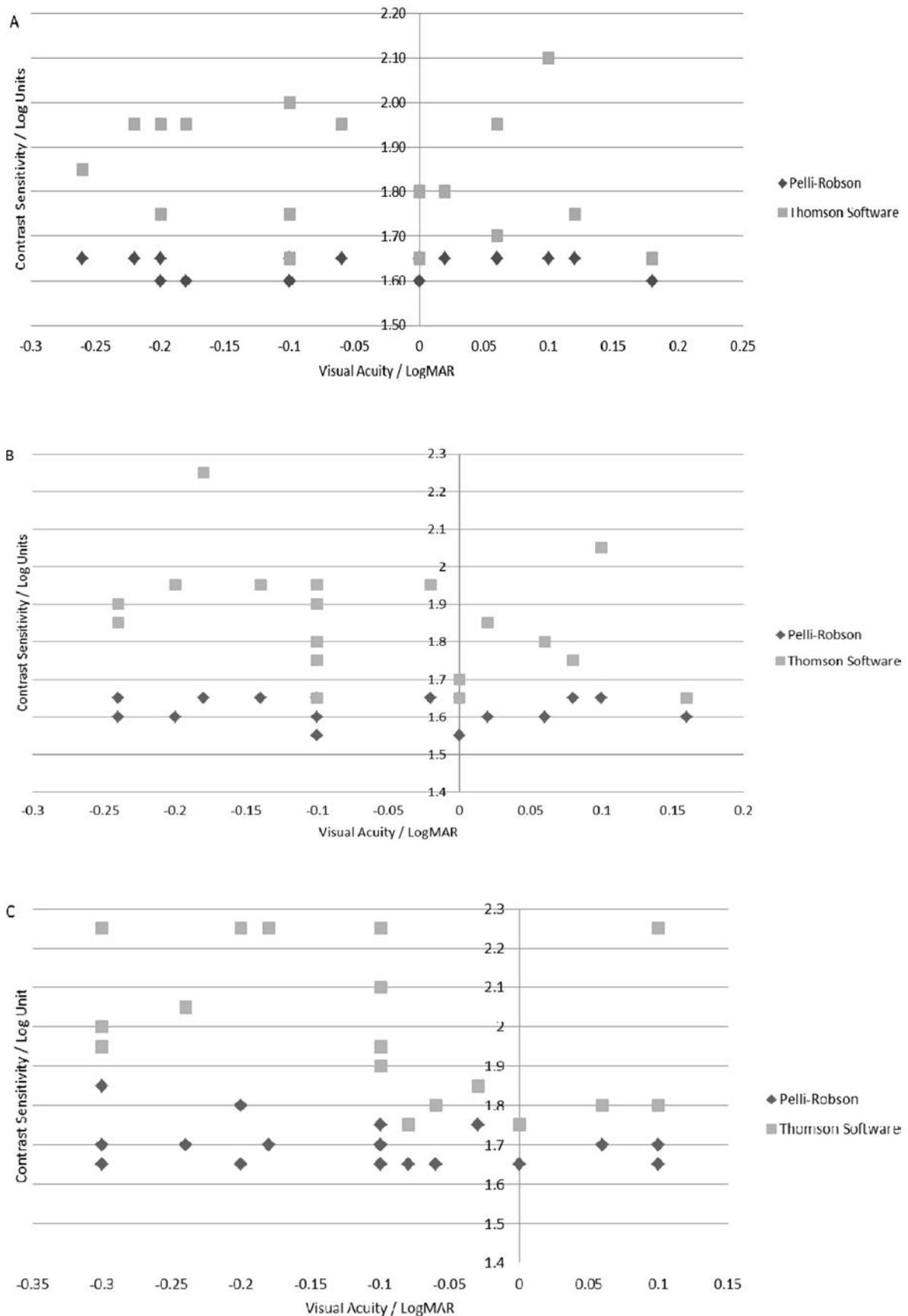


Fig. 2. The relationship between contrast sensitivity and visual acuity score of the right eye (A), left eye (B) and binocular data (C).

suggested that a cathode ray tube (CRT) display may show better results when testing individuals with lower contrast sensitivity levels. In addition, they suggested that the lack of agreement between the Pelli-Robson and Test Chart 2000 may be due to the high luminance of the LCD screen. However, there is no clinical evidence to suggest that a CRT screen would be more suitable than the LCD screen.

Some studies previously found that the computerised charts produced similar or even higher test-retest repeatability. Distinct advantages of using the computerised charts include the fact that the optotypes are randomly presented, the background illumination remains constant and the visual acuity score can be automatically calculated. Some of the computer-based software programs also provide an option of assessing low-contrast visual acuity, but only a limited number of studies have validated these tests.<sup>20,22</sup> Ehrmann *et al.*<sup>22</sup> compared the low-contrast Bailey-Lovie chart against low-contrast letters (British Standard letters as used on the Bailey-Lovie chart) on the Test Chart 2000 Pro displayed on an LCD screen. The testing distance was 6 m for both tests. They demonstrated a good correlation between the paper and computerised chart, and a comparable test-retest repeatability for the two tests. This disagrees with the weak agreement and poorer repeatability found with the Test Chart 2000 compared with the Pelli-Robson chart tested at 1 m.<sup>20</sup> The coefficient of repeatability for the Test Chart 2000 was found to be poor by Thayaparan *et al.*<sup>20</sup> when compared with the Pelli-Robson and Mars charts, with a value of 0.182 for the Pelli-Robson, 0.121 for the Mars chart and 0.238 for the Test Chart 2000. It is important to determine the coefficient of repeatability with newer Thomson software, as this would assess whether the repeatability has improved.

The relationship between visual acuity and contrast sensitivity was also assessed and was found to be weak when tested monocularly and with both eyes open for both contrast sensitivity tests. For example there were participants who showed the same contrast sensitivity value but vastly different visual acuity measurements; a contrast sensitivity value of 1.50 log units was obtained in two different participants with visual acuities of 0.18 and -0.22 logMAR. However, with the small sample size of this study it cannot be conclusively determined that the two factors are not directly related. A study by Misra *et al.*<sup>23</sup> found there was an inverse correlation between contrast sensitivity and visual acuity in patients with proliferative diabetic retinopathy. As our study was done with normals this relationship was not found. Therefore this demonstrates that these two visual functions should be assessed independently of each other and not directly compared with each other. This is evident in the study by the Cryotherapy for Retinopathy of Prematurity Cooperative Group, who found that participants with severe ROP showed a higher contrast sensitivity score than visual acuity score.

There were some limitations in the study conducted. It would be beneficial if there were repeat measurements to test the repeatability and reliability of the tests; however, this was not possible due to the limited time allocated to collect the data. Another limitation was the small sample

size. If there had been more time, a larger sample size would have been used. It also may have been appropriate to administer a short questionnaire after the assessment of the participants to ascertain which contrast sensitivity test the patients found easier and preferred to do.

## Conclusion

This study compared the contrast sensitivity values obtained with the Test Chart 2000 Xpert and the Pelli-Robson test in a group of young normal adults. The study found that the two tests were not comparable and the values were consistently higher with the computerised Test Chart 2000 Xpert. It is recommended that the two tests not be used parallel to each other in clinic; however, due to some limitations of this study this cannot be conclusively stated. Furthermore, the study found that there was a weak relationship between visual acuity and contrast sensitivity, therefore suggesting that these two visual functions should be analysed independently. Further studies including repeated normative and patient data are needed to validate the Test Chart 2000 Xpert as a method of assessing contrast sensitivity.

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