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PELLI-ROBSON CONTRAST SENSITIVITY ON 122 CHILDREN AGED SIX TO TWELVE YEARS

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Abstract

The importance of comparing the results of contrast sensitivity tests to age related normals has been demonstrated in numerous studies. To date no studies have shown normal results on children using the Pelli-Robson chart.
This study outlines the Pelli-Robson test and gives the results for 122 visually normal children aged between six and twelve years.
Results demonstrated a mean score on the Pelli-Robson chart of 1.861 log units in children of this age group. These findings are similar to those reported for young adults.
Key words: *Pelli-Robson, contrast sensitivity in children, age related normals.*

INTRODUCTION

For many years visual acuity has been routinely assessed using a Snellen's vision chart or its equivalent. The shortcoming with this procedure is that the visual world contains very few high contrast small figures made up of sharp black boarders on a white background. Much of our visual world is comprised of subtle shades of low contrast, different sized objects. Over the last decade it has become possible to measure such low contrast by using contrast sensitivity tests.

Contrast sensitivity testing is a technique which provides a measure of visual sensitivity. There are a number of contrast sensitivity tests commercially available which are quick and simple to administer. These include the Vistech VCTS charts, Vistech Multi Contrast test system (MCTS), Vector Vision CSV 1000 test and the American Optical Test Plates or Arden Gratings. These tests use sine wave gratings, (striped lines) to test contrast sensitivity. These gratings are presented at different orientations and at contrasts varying from almost 100% (black on white) to 'shades of grey'. The width of the gratings is expressed as the number of cycles per degree (cpd) subtended at the nodal point of the eye (Figure 1). This width is known as the spatial frequency.

Grating widths range from high spatial frequencies (for example 18 cpd) which are narrow striped lines to low spatial frequencies which are very widely spaced striped lines (for

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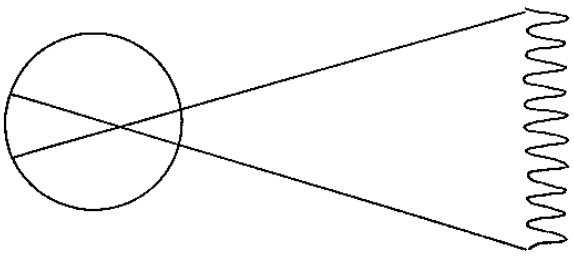
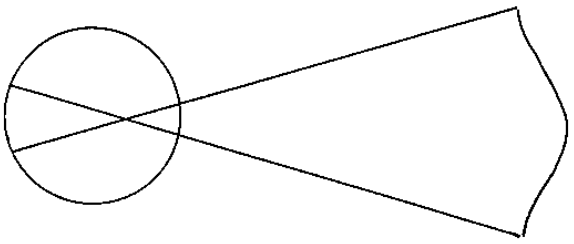


NARROW GRATINGS (STRIPES); HIGH SPATIAL FREQUENCY (10 cycles per degree)



WIDE GRATINGS (STRIPES); LOW SPATIAL FREQUENCY (1 cycle per degree)

Figure 1: Spatial Frequency. The width of a grating is determined by the number of cycles of the grating per degree (cpd) subtended at the nodal point of the eye. Top: High spatial frequency narrow gratings. Bottom: Low spatial frequency wide gratings.

example 1.5 cpd). For any given grating size (spatial frequency) there is a level of contrast known as contrast threshold below which the grating is invisible. Thus contrast threshold represents the minimum contrast at which that size grating is visible.

When performing the above mentioned contrast sensitivity tests the clinician is measuring the contrast threshold at each different spatial frequency giving a range of results. When plotted on a score sheet a contrast sensitivity function curve is created (Figure 2).

In humans contrast sensitivity is maximum when tested using gratings with a spatial frequency of 6 cpd.[1] This is known as mid to low spatial frequency. Conventional visual assessment using Snellen's charts only give an indication of the patients ability to see high spatial frequencies (at very high contrasts) and they give no information about mid and low spatial frequencies.[1] To obtain accurate measurement of high spatial frequencies, refractive errors must be fully corrected. High spatial frequency gives the clinician information about sight when reading for example.[1] Mid and low spatial frequencies provide information about the visibility of larger objects such as face recognition and the patient's orientation and mobility vision.[2,3,4]

The major difference between the above mentioned contrast sensitivity tests and the Pelli-Robson chart is that the Pelli-Robson chart uses letters of constant size (low spatial frequency; 1 to 2 cpd)[5] rather than gratings that decrease in size. Hence the Pelli-Robson chart gives a single measure of contrast sensitivity (known as peak contrast sensitivity) rather than a contrast sensitivity function curve as seen in Figure 2.

Pelli et al[5] argued that letters were preferable to grating targets because letters were more familiar to patients. This is especially relevant when testing children. Pelli also suggested that, as letters consisted of a mixture of both vertical and horizontal square wave gratings and oblique and curved contours, more of the visual system was tested than the contrast sensitivity tests mentioned above which use sine wave gratings at particular orientations.

The reason that Pelli et al[5] used constant and relatively large sized letters was based on the

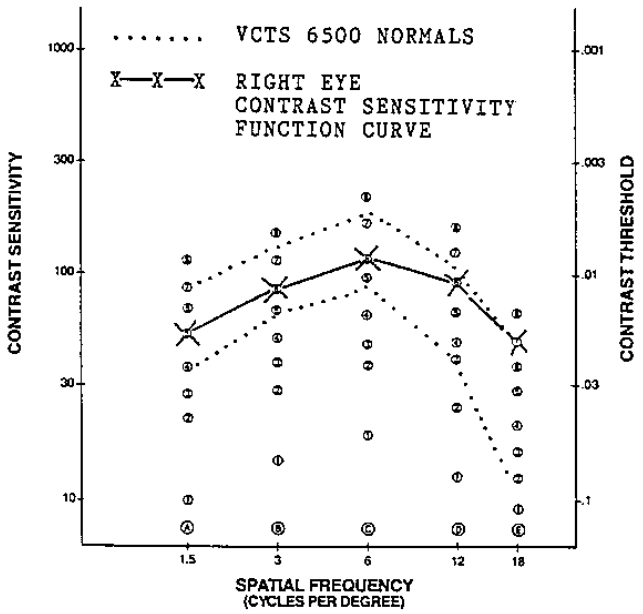


Figure 2: Contrast Sensitivity Function Curve on the Vistech VCTS 6500 test.

finding by Legge et al[6] that contrast sensitivity is reduced at high spatial frequency in subjects with normal vision. As a result, Pelli et al[5] argued that to ascertain if patients with normal vision have abnormal contrast sensitivity, only larger targets (lower spatial frequency) were needed.

The literature reveals that contrast sensitivity is an important diagnostic tool for assessing visual deficit in a number of ocular conditions including amblyopia[7,8,9] refractive error and astigmatism,[10] glaucoma,[11] cataract,[12] macular disease,[13] multiple sclerosis,[14] optic neuritis,[15] corneal oedema[16] and cerebral lesions.[17] In a number of these diseases the visual acuity remains normal.

More recent publications have demonstrated the effect of age on the results of contrast sensitivity tests.[18-29] Searching the literature for population normal scores for the Pelli-Robson chart revealed one publication in which scores for visually normal young adults (mean age 22.5 years; SD ± 4.3 years) and older adults (mean age 70.2 years; SD ± 6.7 years) were reported.[30] The mean score was 1.88 log units or above for young adults and 1.65 log units or above for the older subjects. No studies using the Pelli-Robson chart on children were found on CD Rom Medline searching.

The aim of this paper therefore was to ascertain normal Pelli-Robson chart contrast sensitivity scores for children aged between six and twelve years old.

METHODS

(a) Patient Selection

One hundred and twenty two school children aged between six and twelve years (mean age 8.1; SD ± 1.4 years) had their contrast sensitivity assessed using the Pelli-Robson chart. There were 56 males and 66 females. The children were part of a larger study of children being tested to establish normal levels for the Vector Vision CSV 1000 contrast sensitivity test. (The results of the CSV 1000 test will be the subject of another publication currently in preparation.)[31]

All children attended the same primary school in Western Sydney and their parents had given written permission for their children to be assessed. Children were selected at random from their classrooms. In order to be included in the study all children had to have normal visual acuity (6/6 or better in either eye) without glasses on both the Snellen chart and the logMAR chart, no strabismus and a 550 seconds of arc on the Lang stereo test. Testing was performed with natural pupil size.

(b) Pelli-Robson Chart

The Pelli-Robson chart consists of eight lines of letters. There are two groups of three letters ('triplets') on each line. Letters in each individual 'triplet' are the same contrast. The 'triplet' in the top left hand corner of the chart has the highest contrast (100% contrast) and the 'triplet' in the bottom right hand corner has the lowest contrast (0.9% contrast).[32] The contrast in each successive group decreases by a factor of $1/\sqrt{2}$ (or 0.15 log units) from the top left to the bottom right corner. The letters are all the same size (4.9 cm × 4.9 cm; that is slightly smaller than a Snellen 6/36 letter). When viewed at a distance of one meter each letter subtends 1.5 degrees at the nodal point of the eye. It has been suggested by Pelli et al[5] that the spatial frequency of each letter is between one and two cpd although, as Elliot et al[30] point out this has not been experimentally verified.

The letters used in the Pelli-Robson chart are Sloan letters C, D, H, K, N, O, R, S, V, Z. With the exception of the letter C, all the letters have very high legibility.[33] (The letter C was found to be easily confused with the letter O). Letters are printed on both sides A (chart 4K) and B (chart 2K) of the Pelli-Robson chart. As Elliot et al[30] demonstrated that there was no statistically significant difference between scores on sides A and B all subjects were tested on side A (chart 4K) in this study.

When looking at Figure 3, a Pelli-Robson score sheet, the letters on the second bottom row on the left, for example, 'KCH' have a contrast of 1.80 log units. Those on the right 'ODK' have a contrast of 1.95 log units. (The score sheet shows all the letter 'triplets' on side A of the Pelli-Robson chart printed at 100% contrast. The contrast threshold (log unit) is printed in the margin next to each 'triplet' of letters).

PELLI-ROBSON CONTRAST SENSITIVITY TEST

0.00	V	R	S	K	D	R	0.15
0.30	N	H	C	S	O	K	0.45
0.60	S	C	N	O	Z	V	0.75
0.90	C	N	H	Z	O	K	1.05
1.20	N	O	D	V	H	R	1.35
1.50	C	D	N	Z	S	V	1.65
1.80	K	C	H	O	D	K	1.95
2.10	R	S	Z	H	V	R	2.25

Right Eye

Log Contrast Sensitivity: _____

Acuity: _____

Correction: _____

Pupil Diameter: _____ mm

0.00	V	R	S	K	D	R	0.15
0.30	N	H	C	S	O	K	0.45
0.60	S	C	N	O	Z	V	0.75
0.90	C	N	H	Z	O	K	1.05
1.20	N	O	D	V	H	R	1.35
1.50	C	D	N	Z	S	V	1.65
1.80	K	C	H	O	D	K	1.95
2.10	R	S	Z	H	V	R	2.25

Binocular

Log Contrast Sensitivity: _____

Acuity: _____

0.00	V	R	S	K	D	R	0.15
0.30	N	H	C	S	O	K	0.45
0.60	S	C	N	O	Z	V	0.75
0.90	C	N	H	Z	O	K	1.05
1.20	N	O	D	V	H	R	1.35
1.50	C	D	N	Z	S	V	1.65
1.80	K	C	H	O	D	K	1.95
2.10	R	S	Z	H	V	R	2.25

Left Eye

Log Contrast Sensitivity: _____

Acuity: _____

Correction: _____

Pupil Diameter: _____ mm

Name: _____

Age, Sex: _____

Diagnosis: _____

Medications: _____

Date: _____

Examiner: _____

Comments: _____

PELLI-ROBSON CONTRAST SENSITIVITY CHART 4K. The above log contrast sensitivities are correct to within ±0.05 at the time of calibration of the chart. Copyright © 1988 by Metropia Ltd. Made by Metropia Ltd in U.K. Reorder Cat. No. 7002252 from Clement Clarke Inc, 3128-D East 17th Avenue, Columbus, OH 43219, U.S.A., (800)-848-8923, or Clement Clarke International Ltd, 15 Wigmore Street, London W1H 9LA, U.K., (01)-5808053.

Figure 3: Pelli-Robson Score Sheet. (The numbers in the margins next to each 'triplet' of letters gives the log contrast sensitivity corresponding to the letters in the group. For example, the letters 'KCH' have a score of 1.80 log units.)

(c) Testing Procedure

The Pelli-Robson test was administered in the same way as a Snellen's chart in that the patient was asked to identify the letters in each line of the test. The patients were tested binocularly standing one meter from the chart.

Patients were instructed to read the letters across each row. Children were encouraged to look carefully for letters towards the bottom of the chart. The lowest contrast 'triplets' in which at least two of the three letters were named correctly was recorded as the contrast threshold (as per directions in the manual). Results were recorded on score sheets. The contrast threshold is recorded as the log of the reciprocal of contrast sensitivity. As previously mentioned, on the score sheet this value is printed in the margin next to the 'triplets' of letters (Figure 3).

The light level used for the testing was 85 cd/m^2 which is the level suggested in the manual.

(d) Statistical Methods

For all the visual acuity and contrast sensitivity scores the mean, standard deviation and range were calculated. An analysis of variance (ANOVA) was used to determine the effect of age on scores and a correlation analysis was then done to look for any linear association between age and score. The effect of sex on contrast sensitivity scores was determined by a t test on the population means. The level of probability used was $p < 0.05$.

RESULTS

VISUAL ACUITY: The mean visual acuity was 6/5⁺ for both the right and the left eye with >67% of eyes scoring 6/5. There was no statistically significant difference between the two eyes.

PELLI-ROBSON: The mean contrast threshold was 1.861 + 0.98 log units (second bottom row) with scores ranging from a low of 1.65 log units to a high of 2.10 log units (Table 1).

TABLE 1
Pelli-Robson chart; range and distribution of scores

Score (log units)	Number of children
1.65	9
1.80	56
1.95	52
2.10	2

ANOVA revealed that there was no significant difference in scores for children aged 8 years and over. However, the scores for children aged six and seven years were minimally significantly worse than those aged 8 and over (Table 2).

TABLE 2
Mean scores for age group 6-7 years and age group 8-12 years

Age group (years)	Number of children	Mean score (log units)
6-7	73	1.8452 + 0.96
8-12	49	1.8852 + 0.97

The results of the correlation coefficient analysis demonstrated that there was no linear relationship between the scores from the two age groups ($r = 0.1807$). This suggested that the difference in scores, although significant, was so small that it would not be clinically detectable.

SEX: The t test revealed that the sex of the child did not affect the score. The males ($n = 56$) mean score was 1.8616 log units and females ($n = 66$) mean score was 1.8614 log units; $p = 0.989$.

DISCUSSION

When comparing the results of the present study to the results previously reported by Elliot et al on visually normal adults using the Pelli-Robson chart[30] it is apparent that the scores obtained by the children (mean age 8.1 years) in the present study were similar to the results reported on young adults (mean age 22.5 years). The six to twelve year old children in the present study had a mean Pelli-Robson score of 1.86 + 0.98 log units and the young adults in Elliot's study had a mean Pelli-Robson score 1.88 + 0.88 log units. Thus the present study supports Elliot's finding that the majority of normal patients under the age of 50 will score 1.80 log units or better.

The finding of a minimal effect of age on scores for six and seven year old patients (Table 2) must not be ignored but, as the sample of patients of that age was relatively small, further investigation should be conducted to confirm this.

Previous studies of children's contrast sensitivity have demonstrated that it was essential to use only age related normals as mean scores for children differed from those for adults.[18-29] However, it may be that when measuring peak contrast sensitivity using the Pelli-Robson chart rather than mapping out a contrast sensitivity function curve (using other contrast sensitivity tests), age is not as critical.

Alternately, using letters rather than sine wave gratings is subjectively easier for patients as letters are more familiar[5] therefore when using letters the children's scores may be more easily able to mimic the scores from young adults.

By using the relatively large letters, the Pelli-Robson chart detects contrast while being insensitive to defocus. The Pelli-Robson test measures contrast sensitivity irrespective of the retinal image quality and it is especially insensitive to optical blur.[34] Conversely, the contrast sensitivity tests like the Vistech test were designed to detect the loss of contrast sensitivity that is associated with defocused images due to either optical defocus or pathology[34] as they incorporate high contrast sensitivity gratings. The studies reporting the effect of age on contrast sensitivity using the Vistech contrast sensitivity test found that age had a more marked effect on contrast sensitivity at high spatial frequency,[28,29,35] a spatial frequency which the Pelli-Robson chart does not test.

In this study the sex of the child had no effect on the score. Once again this differs from previous reports where male children have performed better than female children in this age group.[28,29,35]

CONCLUSIONS

This study demonstrated that the mean Pelli-Robson chart score for 122 children aged between six and 12 years was 1.861 log units. This finding was similar to that reported by Elliot et al for visually normal young adults.

The Pelli-Robson chart is quick and easy to administer, especially when compared to the other readily available contrast sensitivity tests. This is because young children are very familiar with letters and the task of naming letters. The Pelli-Robson chart takes less time to administer than the Vistech VCTS test of the Vector vision test. However clinicians must remember that the Pelli-Robson test was not designed to be sensitive to retinal image quality and it is especially insensitive to optical blur.

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