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ORIGINAL ARTICLE

Reliability and Validity of the Melbourne Edge Test and High/Low Contrast Visual Acuity Chart

SHARON A. HAYMES, BScOptom, MOptom, PhD, FVCO, FAAO and JASON CHEN, BOptom, PgDipAdvClinOptom

Department of Optometry and Vision Sciences, The University of Melbourne, Melbourne, Australia (SAH), Clinical Vision Research Australia, Melbourne, Australia (SAH), and the Victorian College of Optometry, Melbourne, Australia (JC)

ABSTRACT: *Purpose.* The purposes of the study were to investigate the test-retest reliability and the validity of new versions of the Melbourne Edge Test (MET) and the High/Low Contrast Visual Acuity (H/LCVA) chart and to investigate the agreement between the original and new versions. *Methods.* The MET original photographic version, MET new light box version, H/LCVA Chart original photographic version, H/LCVA Chart new printed version, and the Pelli-Robson chart were administered twice to one eye of 22 subjects with low vision and 20 soft contact lenses wearers. *Results.* For the low vision group, the test-retest 95% limits of agreement were ±5.2 dB for the MET new light box version and ±0.39 logarithm of the minimum angle of resolution (logMAR) for the LCVA component of the H/LCVA new printed version. For the soft contact lens group, the test-retest 95% limits of agreement were ±2.1 dB for the MET new light box version and ± 0.26 logMAR for the LCVA component of the H/LCVA new printed version. Moderate to high correlations were obtained between contrast sensitivity tests, thus providing evidence of validity. Scores obtained for the new test versions were significantly higher than the original versions ($p < 0.01$). *Conclusions.* Of all the tests administered, the MET original photographic version and the Pelli-Robson Chart had the highest test-retest reliability for the low vision group. For the soft contact lens group, the H/LCVA original version (low contrast letters, 18% Weber) and the Pelli-Robson Chart had the highest reliability. (Optom Vis Sci 2004;81:308–316)

Key Words: contrast sensitivity, low contrast visual acuity, Melbourne Edge Test, Pelli-Robson Chart, test-retest reliability

Several clinical tests of contrast sensitivity are now available. There are numerous publications in the scientific literature of their use, for example, in predicting real world function[1–8] and in assessing change in visual function, such as screening for visual pathway disorders,[9, 10] determining the effectiveness of ocular treatments,[11–14] and evaluating refractive error correction modalities.[15–18] In particular, the Melbourne Edge Test (MET) and the High/Low Contrast Visual Acuity (H/LCVA) chart are widely used in Australia. Recently, the production methods used for these tests have changed, and their psychometric properties have yet to be reported in the scientific literature.

The MET[19–21] was originally produced by Verbaken of Australian Vision Charts. It is a small (30 × 25 cm), portable test that comprises 20 disks, each 25 mm in diameter. The test is arranged with four lines of five disks. Each disk contains an edge, which decreases in contrast from the top to the bottom of the chart. The person being tested must indicate at which of four possible orientations (45, 90, 135, or 180°) they see the edge in each disk. Edge detection is considered to be related to peak contrast sensitivity. The contrast of each edge decreases on a decibel (dB) scale, in which 1 dB = $10\log_{10}$(Michelson contrast sensitivity).[21, 22] The edges range in contrast from 1 to 24 dB (−0.10 to −2.40 log Michelson contrast sensitivity units) and are mounted onto a gray background card. The higher contrast edges, within the disks across the top line, reduce in 2 dB steps and thereafter in 1 dB steps. The recommended testing distance is 40 cm, and the recommended background luminance is 18 to 80 cd/m^2. In a study of 499 eyes with no ocular disease and high-contrast distance visual acuity equal to or better than 20/25 (0.1 logMAR), Verbaken and Johnston found that normal values for the MET were at least 18 dB for those younger than 65 years of age and 16 to 17 dB for those older than 65 years of age.[20, 21] They suggested that a loss of more than 2 dB between tests was significant.

The original MET was produced using a two-exposure photographic technique on semi-matte paper.[19] In the late 1990s, the production method was changed, such that the test is now produced using a computer-controlled photographic typesetter to print dots of varying density (J. Verbaken, personal communication, 2003). The typesetter uses a laser beam to expose the test edges on lithographic film. The transparent film is mounted on a light box, which can be battery or mains operated. The new version again ranges in contrast from 1 to 24 dB, but it has three rather than four rows of five edges. The first two rows of edges increase in 2 dB steps and thereafter in 1 dB steps. This new version is assembled and distributed by the National Vision Research Institute.

During the development of the MET, Verbaken also produced the H/LCVA Chart.[23] It is a small (40 × 27 cm), portable test based on the accepted standard, the Bailey-Lovie logMAR design.[24] The test comprises a high-contrast and low-contrast letter chart positioned side by side. Thus, the design facilitates the direct comparison of high-contrast visual acuity (HCVA) and low-contrast visual acuity (LCVA). The contrast of each miniature chart is fixed (90% and 10% Michelson contrast or 95% and 18% Weber contrast for the high- and low-contrast letters, respectively), with letter size decreasing from the top to the bottom of the chart in 0.1 logMAR steps. There are 12 rows of letters, with five letters per row. The chart was designed for a 4 m testing distance, but it can be used at any distance. Based on 4 m, the range of letter sizes is equivalent to 20/6 to 20/80 (−0.5 to 0.6 logMAR). The recommended background luminance is 85 cd/m^2.[23] Population norms were provided by Wood and Bullimore.[25] They investigated 91 subjects, aged 21 to 82 years, with no ocular disease and distance visual acuity better than 20/25 (0.1 logMAR). With best refractive error correction, mean LCVA was 0.01 logMAR in the subgroup aged 20 to 29 years and 0.15 logMAR in the subgroup aged 60 to 69 years. For each of these subgroups, the mean difference between HCVA and LCVA was −0.16 logMAR and −0.20 logMAR (just more than 1.5 to 2.0 lines of letters), respectively. Similar results have been obtained by Lovie-Kitchin and Brown using Bailey-Lovie HCVA and LCVA charts.[26]

The H/LCVA Chart was originally produced using traditional photographic techniques. A photographic negative is made from a computer file of the chart and then contact printed on photographic paper (Verbaken, personal communication, 2003). Now, the charts are being screen-printed using calibrated gray ink on a white card. They are manufactured and distributed by the National Vision Research Institute.

The aim of this study was to investigate the psychometric properties of the new version of the MET and the H/LCVA Chart. More specifically, it was to investigate test-retest reliability of the new versions, agreement between the original and new versions, and to compare the reliability of the MET and the H/LCVA Chart to the reliability of the widely used Pelli-Robson Chart. Furthermore, the aim was to investigate the validity of the tests by examining their intercorrelations. We chose to study groups for which these tests are typically used to assess visual function.

METHODS

Subjects

Two groups of subjects were recruited. Group 1, the low vision group, comprised 22 subjects who were recruited from the Vision Australia Foundation Kooyong Low Vision Clinic. The criteria for inclusion were that subjects had to be older than 18 years of age, they had been diagnosed with an ocular disease by an ophthalmologist or optometrist, that they had distance HCVA between 20/40 and 20/1000 in at least one eye and they had stable vision during the previous 3 months. The stability of vision was determined by comparing current measures of distance visual acuity, ophthalmoscopy, and slit-lamp biomicroscopy findings with low vision clinic records and reports from referring practitioners. Subjects were excluded if distance visual acuity had changed by more than one line of letters (0.1 logMAR) or if new ocular signs were observed. Subjects were also excluded if their history indicated they had a general health condition associated with cognitive impairment.

Group 2, the young soft contact lens group, comprised 20 subjects who were recruited from the University of Melbourne student population. The criteria for inclusion were that subjects had to be aged between 18 and 35 years, had distance HCVA better than 20/32, and had worn nontinted spherical soft contact lenses for more than 6 months. Subjects were excluded if their history indicated the presence of any ocular disease.

The study design and protocol conformed to the tenets of the Declaration of Helsinki. Subjects were informed of the nature of the study, and written consent was obtained before participation. The study was approved by the institutional review board.

Demographic Variables

The following demographic variables were recorded for the low vision group: date of birth, ocular conditions, general health history (including systemic conditions and medications), refractive error (current spectacle correction and refraction), and distance HCVA. Similarly, for the soft contact lens group, the following variables were recorded: date of birth, refractive error (current soft contact lens correction and refraction), and distance visual acuity. For both groups, distance visual acuity was measured using a retroilluminated high-contrast Bailey-Lovie logMAR letter chart.[24] The room and chart illumination were standardized such that the background luminance of the chart was 120 cd/m^2, which was within the recommended range.[27]

Contrast Sensitivity Measures

The following clinical contrast sensitivity charts were administered twice to each subject: the Pelli-Robson Chart (Clement Clarke, Inc., London, United Kingdom), MET 1986 original photographic version, MET 1998 new light box version, H/LCVA Chart 1986 original photographic version, and H/LCVA 1995 new printed version. Hereafter, the versions of the MET and the H/LCVA Chart will be referred to as simply original or new. The contrast of each chart was verified using a Spectra Pritchard Photometer (Photo Research Inc., Chatsworth, CA). The mean of three measures indicated values specified by the manufacturers were accurate to within ±10% for the MET and Pelli-Robson charts, for those contrasts high enough to be measured photometrically. The mean contrast of the low-contrast letters of the H/LCVA original version was 18% Weber (or 10% Michelson) and for the H/LCVA new version was 11% Weber (or 6% Michelson).

The Pelli-Robson Chart[28, 29] was administered at a test distance of 1 m with a background luminance of 50 cd/m^2. The chart comprises letters that are arranged in groups of three, or triplets. There are eight rows, with two triplets per row. The triplets decrease in contrast from the top to the bottom of the chart in steps of $1/\sqrt{2}$, or 0.15 log units. The contrast of the triplets ranges from 0.00 (highest contrast letters) to -2.25 log units (lowest contrast letters), whereby the log units are $\log_{10}$ (Weber contrast sensitivity). However, results are typically reported as positive, with higher values indicating better contrast sensitivity. Letter size is fixed and at a test distance of 1 m, the Pelli-Robson Chart is considered to provide a measure near to the peak of the contrast sensitivity function. It is produced using a computer-controlled phototypesetter to generate variable-dot-densities and printed using offset lithography.[28] Normal Pelli-Robson Chart values are 1.88 log units for younger persons and 1.75 log units for older persons.[30, 31]

For the Pelli-Robson Chart, subjects were directed to begin reading the letters across the top row and to continue reading down until at least two of the three letters in a group were called incorrectly. Subjects were asked to look at a group of letters for at least 20 s, as this is often required before letters can be perceived at near threshold levels.[32] Subjects were also encouraged to guess. A call of "C" for "O" or vice versa was permitted and counted as correct.[33] To maximize reliability, the per-letter method of scoring was used, whereby each letter read correctly was assigned a value of 0.05 log contrast sensitivity units.[32] To reduce the effects of memorization between testing, the subjects were directed to read each group of letters in the forward direction on one testing occasion and in the reverse direction on the other testing occasion. This procedure was facilitated by the use of a pointer.

Both versions of the MET were administered at a test distance of 40 cm. The background luminances of the MET new light box version and the original photographic version were 340 cd/m^2 and 30 cd/m^2, respectively. Subjects were directed to identify the orientation of the edge within each circular test patch, beginning at the top of the chart. They were required to continue until two consecutive incorrect responses were made. Again, subjects were encouraged to look at each test patch for at least 20 s and to guess. Contrast sensitivity was recorded as the last correctly identified edge, in dB. To reduce the effects of memorization between testing, the MET was administered in its usual orientation on one testing occasion and rotated 90° on the other testing occasion. Again, this procedure was facilitated by the use of a pointer to direct a subject's attention to the next appropriate test patch.

Both versions of the H/LCVA Charts were administered at 60 cm for the low vision group and at 3 m for the soft contact lens group. The test distances were selected to present an appropriate range of letter sizes to each group, thereby avoiding floor and ceiling effects. The background luminance of the H/LCVA Chart new printed version and the original photographic version was 88 cd/m^2 and 92 cd/m^2, respectively. Subjects were directed to begin reading the low contrast letters at the top of the chart. They were required to continue reading down the chart until at least three of the five letters on a line were called incorrectly. Again, subjects were encouraged to look at each line for at least 20 s and to guess. LCVA was scored using the per-letter method, which has been shown to increase the reliability of letter charts based on logMAR principles, such as this one.[32, 34, 35] Thus, each letter read correctly was assigned a value of 0.02 logMAR. After reading the low contrast letters and determining the LCVA score, subjects were directed to continue reading the juxtaposed high contrast letters. HCVA was tested and scored in the same manner as LCVA. To reduce the effects of memorization between testing, the H/LCVA Charts were administered at different test distances. On one testing occasion, the charts were administered at the distances given above, and on the other testing occasion, they were administered at 25 cm for the low vision group and at 2 m for the soft contact lens group. In this way, a different sequence of letters was presented near the subject's visual acuity threshold.

Procedure

All the data were collected at the Kooyong Low Vision Clinic in the case of the low vision group and at the Department of Optometry of the University of Melbourne in the case of the soft contact lens group. The illuminance was standardized to 350 lux in both testing rooms and calibrated at the commencement of the experimental sessions. All lighting measurements were made using a Hagner Universal Photometer (B. Hagner AB, Solna, Sweden).

Each of the contrast sensitivity tests was administered to the subjects twice on the same day. One researcher collected all the data for the low vision group, and another researcher collected all the data for the soft contact lens group. The tests were administered to one eye. When both eyes met the inclusion criteria, the tests were administered to the eye with the better distance visual acuity for the low vision group and to the right eye for the soft contact lens group. In the case of the low vision group, all measures were made using the best refractive error correction for the test distance and age of the subject. In the case of the soft contact lens group, the current soft contact lenses were used. The order of test presentation was randomized. Also, the alternative test versions and distances (used to minimize memorization effects) were randomly assigned to the test or retest.

Analysis

All data were doubly entered into a Microsoft Excel 2000 spreadsheet (Microsoft, Redmond, WA) and analyzed using Minitab Statistical Software Release 13.1 (Minitab, Inc., State College, PA). The analysis included descriptive statistics based on the mean, standard deviation, and range, because all the measurements were continuous. The methods of Bland-Altman were used to investigate the test-retest reliability and the agreement between test versions.[36] The means of the differences and the 95% limits of agreement (LoA) were determined. The intraclass correlation coefficient was also determined as an indicator of test-retest reliability. When the distribution of measurements met the assumption of normality, a t-test was used to detect a statistically significant difference between the original and newer versions of the MET and the H/LCVA Charts. The Pearson correlation coefficient was used to examine the associations between the various contrast sensitivity tests administered. When normality assumptions were not met, the Spearman correlation coefficient was used.

RESULTS

The mean age of the 22 subjects in group 1, the low vision group, was 74 years (range, 31–92 years). Twelve subjects had age-related macular degeneration. The remainder of the subjects had primary ocular disease that could be categorized as inherited retinal dystrophy, glaucoma, myopic degeneration, or retinal vascular disease. The mean age of the 20 subjects in group 2, the soft contact lens group, was 22 years (range, 18–32 years). The mean soft contact lens correction for the group was −3.75 D (range, −0.50 to −9.50 D). Mean values of vision measures for both groups are given in Table 1.

Test-Retest Reliability

The test-retest reliability (Bland-Altman method) and the intraclass correlation coefficient for all tests are provided in Table 2. Examination of the Bland-Altman plots of mean test and retest score against the difference between scores (retest minus test), indicated that differences did not vary in any systematic way over the range of measurement in all cases.

It should be noted that, for the soft contact lens group, these analyses were inappropriate with respect to the MET new version, because all subjects obtained the highest score possible (24 dB). Also, the Ryan-Joiner test indicated the distributions of the MET original version and the Pelli-Robson Chart scores for the soft contact lens group departed from normality ($p < 0.05$), with scores being skewed toward the high ends of the scales. However, the differences between test and retest scores did not show a significant departure from normality (Ryan-Joiner test, $p > 0.05$). Therefore, the Bland-Altman method was used to analyze the test-retest reliability.

Test Version Agreement

The agreement between the original and new versions for the MET and the H/LCVA Chart (Bland-Altman method) is provided in Table 3. Examination of the Bland-Altman plots of the mean original and new version score against difference between scores (new minus original version) indicated that differences did not vary in any systematic way over the range of measurement in all cases. Again, it should be noted that, for the soft contact lens group, these analyses were inappropriate with respect to the MET new version data, because all subjects obtained the highest score possible (24 dB). All other distributions were normal (Ryan-Joiner, $p > 0.05$).

Intercorrelations

Correlations between the various types of tests investigated are given in Table 4. For reasons already stated, correlations involving the new MET for the soft contact lens group were not determined. In view of the distribution of the original MET and the Pelli-Robson Chart data for the soft contact lens group, Spearman coefficients rather than Pearson coefficients are given for correlation analyses that included these tests. All coefficients were calculated using the initial test data collected.

DISCUSSION

Several previous studies are relevant to the discussion of the results found in this study. A summary of the methods and findings of these previous studies is given in Table 5. To facilitate comparisons, this table is referred to throughout the discussion.

Melbourne Edge Test

Both versions were appropriate for the low vision group, with a wide spread of scores. However, the new version was inappropriate for the group of soft contact lens subjects studied in this investigation, because a ceiling effect occurred, whereby all subjects scored the scale maximum. We suggest this occurred because the luminance of the MET new light box version was considerably higher than that of the original photographic version. Therefore, it is likely that the new MET would be of no value in testing the visual function of those with normal vision (e.g., in the study of refractive surgery). We recommend the test may be improved by extending the upper end of the scale for subjects with good vision.

The small positive values of mean difference between retest and test indicate scores for both versions of the MET were slightly higher on the retest compared than on the first test (Table 2). For the low vision group, the MET new light box version 95% LoA

TABLE 1.
Mean values of vision measures by subject group[a]

Vision Measure	Low Vision Group			Soft Contact Lens Group		
	Mean (SD)	Range	N	Mean (SD)	Range	N
Bailey-Lovie High Contrast Visual Acuity (logMAR)	0.98 (0.36)	0.36–1.50	22	0.00 (0.07)	−0.12 to 0.16	20
MET new light box version (dB)	11.9 (4.8)	3.0–20.0	22	24.0 (0.0)	na	20
MET original photo, version (dB)	10.5 (3.8)	5.0–18.0	21	23.1 (1.3)	20.0 to 24.0	20
LCVA new printed version (logMAR)	1.24 (0.25)	0.80–1.80	17	0.22 (0.10)	0.06 to 0.46	20
LCVA original photo. version (logMAR)	1.23 (0.31)	0.72–1.84	22	0.14 (0.13)	−0.04 to 0.38	20
LCVA-HCVA new printed version (logMAR)	0.36 (0.24)	0.04–0.98	16	0.23 (0.09)	0.08 to 0.40	20
LCVA-HCVA original photo. version (logMAR)	0.24 (0.15)	0.00–0.54	20	0.21 (0.08)	0.06 to 0.42	20
Pelli-Robson Chart (log units)	1.11 (0.38)	0.45–1.65)	21	1.88 (0.08)	1.80 to 1.95	20

[a] Note that some subjects in the low vision group were unable to perform some of the tests, as indicated by N. Also, the data for one subject in the new LCVA-HCVA and two subjects in the case of the original LCVA-HCVA was excluded. This was because these subjects were able to read all letters on the HCVA chart at the test distance used and therefore, threshold was not determined.

MET, Melbourne Edge Test; LCVA, low contrast visual acuity; HCVA, high contrast visual acuity.

TABLE 2.
Analysis of test-retest reliability by subject group[a]

Test	Low Vision Group			Soft Contact Lens Group		
	Mean Difference Retest-Test	Limits of Agreement (±1.96 SD)	ICC	Mean Difference Retest-Test	Limits of Agreement (±1.96 SD)	ICC
MET new (dB)	0.4	5.2	0.88	na	na	na
MET original (dB)	0.6	3.7	0.89	0.5	2.1	0.58
LCVA new (logMAR)	−0.01	0.39	0.79	0.02	0.26	0.26
LCVA original (logMAR)	0.03	0.35	0.86	0.00	0.18	0.71
LCVA-HCVA new (logMAR)	0.04	0.37	0.60	0.01	0.26	−0.06
LCVA-HCVA original (logMAR)	0.02	0.30	0.40	0.00	0.17	0.37
Pelli-Robson Chart (log units)	−0.01	0.25	0.95	−0.02	0.18	0.52

[a] ICC, intraclass correlation coefficient; na, not applicable (see text for explanation).

TABLE 3.
Analysis of agreement between new and original versions of the tests by subject group[a]

Test Pair	Low Vision Group		Soft Contact Lens Group	
	Mean Difference New-Original	Limits of Agreement (±1.96 SD)	Mean Difference New-Original	Limits of Agreement (±1.96 SD)
MET new light box and MET original photographic (dB)	1.7	4.7	na	na
LCVA new printed and LCVA original photo. (logMAR)	0.13	0.30	0.08	0.17
LCVA-HCVA new printed and LCVA-HCVA original photo. (logMAR)	0.11	0.29	0.02	0.18

[a] na = not applicable (see text for explanation).

TABLE 4.
Correlations between contrast sensitivity tests by subject group[a]

Test Pair	Low Vision Group	Soft Contact Lens Group
	Correlation Coefficient (Pearson)	Correlation Coefficient (Spearman)
MET new light box and Pelli-Robson Chart	0.77[b]	na
MET original photographic and Pelli-Robson Chart	0.78[b]	0.10
LVCA new printed and Pelli-Robson Chart	−0.67[b]	−0.34
LCVA original photographic and Pelli-Robson Chart	−0.72[b]	−0.49[b]
LVCA new printed and MET new light box	−0.45	na
LVCA original photographic and MET new light box	−0.73[b]	na
LVCA new printed and MET original photographic	−0.63[b]	−0.05
LVCA original photographic and MET original photographic	−0.70[b]	−0.26

[a] na, not applicable (see text for explanation).
[b] $P < 0.01$.

were larger than the MET original photographic version 95% LoA (95% LoA ± 5.7 dB and ± 3.2 dB, respectively). For the soft contact lens group, the 95% LoA were ±2.1 dB, or approximately two steps on the MET original photographic version. For comparison, Verbaken and Johnston[21] found that 70% of their subjects had a retest score within 1 dB of the test score, after conversion from their original $20\log_{10}$(contrast sensitivity) scale to the more appropriate $10\log_{10}$(contrast sensitivity) scale (Table 5).[22] Thus, the 95% LoA indicate the MET new light box version had reduced test-retest reliability compared with the original photographic version and that the MET original version had poorer reliability for the low vision group compared with the soft contact lens group.

The reduced test-retest reliability for the MET new version compared with the original version may be because the MET new version has wider steps at the lower end of the scale, which was the effective range of the test for the low vision group. For the MET new version, the scale between 1 and 19 dB increases in 2 dB steps, and from 20 to 24 dB, it increases in 1 dB steps. For the MET original version, the scale between 1 and 9 dB increases in 2 dB steps, and from 10 to 24 dB, it increases in 1 dB steps. Raasch et al.[37] have found that increasing the number of steps by a factor of n improves the reliability of visual acuity measurement by $\sqrt{n}$. Therefore, we suggest that the use of finer steps at the lower end of the MET new light box scale may improve its reliability for those with low vision.

TABLE 5.
Summary of relevant previous studies[a]

Study	Subjects	Methods	Mean (SD)	Test-Retest Reliability
Verbaken and Johnston[21]	N = 497 aged 9–89 years.	Right and left eyes tested at 40 cm, using best refraction, retested after 2 to 3 weeks.	Group 1: MET mean 19.5 dB (SD 3 dB).	Test-retest variation ± 1 dB or less for 70% of subjects[b]
	N = 140 eyes tested twice.	Melbourne Edge Test photographic version.	Group 2 & 3: MET mean 17.5 dB (SD 4 dB).	
	Group 1: N = 499 eyes, no pathology VA ≥ 6/7.5.			
	Group 2: N = 127 eyes, media haze.			
	Group 3: N = 134 eyes, ocular pathology, VA < 6/7.5.			
Elliott and Bullimore[38]	Group 1: N = 24 young, normal vision.	One eye tested, using best refraction, per letter scoring, retested after at least 1 week.	Group 1: Regan 25% mean −0.07 logMAR (SD 0.06), Regan 11% mean 0.05 logMAR (SD 0.08), Pelli-Robson mean 1.86 log units (SD 0.09).	Regan 25% Chart: 95% LoA ± 0.09 logMAR.
	Group 2: N = 22 older, normal vision.	Regan Charts 25% and 11%.	Group 2: Regan 25% mean 0.04 logMAR (SD 0.08), Regan 11% mean 0.19 logMAR (SD 0.10), Pelli-Robson mean 1.80 log units (SD 0.11).	Regan 11% Chart: 95% LoA ± 0.14 logMAR.
	Group 3: N = 33 older, cataract, VA > 6/21.	Pelli-Robson Chart.		Pelli-Robson Chart: 95% LoA ± 0.18 log units.
	N = 41 tested twice (19 from group, 1, 15 from group 2 and 7 from group 3).			
Lovie-Kitchin and Brown[26]	N = 78 aged 21–68 years.	One eye tested, using habitual refractive correction, better eye only, per letter scoring, repeated five times, after 2–3 days.	HCVA mean −0.05 logMAR.	LCVA: 95% LoA ± 0.13 logMAR.
	Normal vision (VA ≥ 6/9.5).	Bailey-Lovie HCVA and LCVA (18%).	LCVA mean 0.16 logMAR.	Pelli-Robson Chart: 95% LoA ± 0.17 log units.
		Pelli-Robson at 3 m.	Pelli-Robson mean 1.74 log units.	
Elliott et al[32]	N = 40 aged 20–79 years.	One eye tested, using best refraction, per letter scoring, retested after 5–14 days.	Pelli-Robson mean 1.83 log units (SD 0.14 log units).	Pelli-Robson Chart: 95% LoA ± 0.20 log units.
	Normal vision (VA ≥ 6/9 or better).	Pelli-Robson Chart at 1 m.		
Reeves et al[40]	N = 126.	One eye tested, using best refraction, 2 out of 3 correct scoring retested after 4–12 weeks.		Pelli-Robson Chart: 95% LoA ± 0.27 log units.
	Representative of a population that would be screened, various ocular pathologies.	Pelli-Robson Chart.		

[a] All contrasts are Weber values. VA, visual acuity (distance high contrast); and LoA, limits of agreement.
[b] After conversion to $10\log_{10}$ (contrast sensitivity) scale.

The poorer reliability for the low vision group compared with the soft contact lens group may have occurred for other reasons. First, those with low vision indeed may be more variable than those with normal vision on retest. Second, members of the soft contact lens group, having better vision and being younger than the low vision group, are likely to show less variability because their scores were limited to a small range at the upper end of the test scale (range, original MET, 20–24 dB). It is not possible for scores near the end of a scale to vary as much on retest as scores that are further away from the end of the scale. The lower correlation coefficient obtained for the soft contact lens group occurred simply because correlation coefficients provide a poor indication of reliability when the range of scores is small, as was the case for the soft contact lens group.[36]

The MET new light box score was 1.7 dB higher on average than the MET original photographic score, for the low vision group ($p < 0.01$) (Table 3). Given the difference in the luminance of the tests, this was expected. It is well known that vision increases with increasing luminance. Furthermore, the magnitude of the difference found in this study is consistent with the findings of Verbaken and Johnston (1.5 dB higher for a MET luminance of 80 cd/m^2 compared with 18 cd/m^2).[21]

High/Low Contrast Visual Acuity Chart

The contrast of the low-contrast letters on the H/LCVA Chart new printed version was lower than those on the original photographic version (11% rather than 18% Weber contrast). Both versions were appropriate for the soft contact lens group, with no limitation of range and a moderate spread of scores. However, a small proportion of the low vision subjects (23%) were unable to see any letters on the new version. This proportion may have been decreased by further reducing the test distance used. Nevertheless, a wide range of scores was observed for most members of the low vision group.

The mean difference between retest and test LCVA score was less than 0.03 log units for both groups (Table 2). For the soft contact lens group, the 95% LoA were ±0.18 logMAR, or almost two steps on the low-contrast chart of the H/LCVA original photographic version. For comparison, using a Bailey-Lovie chart design of the same contrast (18% Weber), Lovie-Kitchin and Brown found 95% LoA of ±0.13 logMAR for their group with normal vision (Table 5).[26] The narrower 95% LoA obtained by Lovie-Kitchin and Brown may have arisen because of the wider range of observed scores in their study. For the soft contact lens group in this study, the LCVA 95% LoA were wider still for the H/LCVA new printed version (95% LoA ± 0.26 logMAR). The closest comparison than can be made is with Elliott and Bullimore's data for a Regan Chart of 11% Weber contrast.[38] They found 95% LoA of ±0.14 logMAR (Table 5). The narrower 95% LoA obtained by Elliott and Bullimore may have arisen because the Regan design has more letters per line than the Bailey-Lovie design, as suggested by Hazel and Elliott.[39] Elliott and Bullimore also investigated 25% and 96% Regan Charts and, as in this study, found narrower 95% LoA for charts of higher contrast.

Similar results were obtained for the low vision group. The LCVA 95% LoA were wider for the H/LCVA new printed version than for the original version. Also, the LCVA 95% LoA were wider for the low vision group than for the soft contact lens group. However, unlike the MET scores, scores for the soft contact lens group were not limited by the scale. Therefore, it is likely that those with low vision are more variable on LCVA retest.

The LCVA score for the H/LCVA new printed version was significantly higher, representing worse LCVA, than the LCVA score for the H/LCVA original photographic version, for both groups ($p < 0.01$). On average, scores were 0.13 logMAR and 0.08 logMAR worse than the original scores for the low vision group and the soft contact lens group, respectively (Table 3). Given the difference in the contrast of the tests, this was to be expected. The magnitude of the differences found in this study are consistent with the findings of Elliott and Bullimore for 11% and 25% Regan Charts.[38] The differences between mean values for the 11% and 25% charts were 0.16 logMAR and 0.12 logMAR for a cataract group and a young, healthy group, respectively (Table 5).

The difference between HCVA and LCVA scores was also analyzed (Tables 2 and 3). The patterns evident in the results are the same as for LCVA score alone (i.e., 95% LoA wider for the new printed version compared with original photographic version and 95% LoA wider for the low vision group compared with the soft contact lens group).

Pelli-Robson Chart

The Pelli-Robson Chart was appropriate for both groups studied, with no upper or lower end limitations of the scale.

The mean difference between retest and test score was approximately zero for both groups (Table 2). The 95% LoA were ±0.18 log and ±0.25 units (one or two steps or triplets) for the soft contact lens and low vision group, respectively. These values are close to those found by others (Table 5). For subjects with normal vision, Elliott et al.[32] found 95% LoA of ±0.20 log units, and Lovie-Kitchin and Brown[26] found 95% LoA of ±0.17 log units. For a group of subjects with ocular disease, Reeves et al.[40] found 95% LoA of ±0.27 log units.

As for the other contrast sensitivity tests investigated, wider 95% LoA (greater test-retest variability) were found for the low vision group compared with the soft contact lens group. Although the range of scores was narrowly distributed for the soft contact lens group, scores did not reach the limit of the Pelli-Robson scale. Therefore, the discrepancy between groups is unlikely to be the result of constrained scores. It is more likely to be the result of an inherent difference in the test-retest variability of those with low vision and those with normal vision.

The 95% LoA indicate greater reliability for the Pelli-Robson Chart in comparison with the MET for both groups (Table 2). Again, this may be the result of the difference in scale increments. It may also be because contrast sensitivity is less at oblique orientations than at horizontal or vertical orientations,[41] so that subjects may see the MET target at different contrast levels depending on whether it is oblique, horizontal, or vertical. Furthermore, the MET is a four-alternative forced-choice test in which targets are presented at one of only four alternative orientations (90, 45, 135, and 180°), whereas the Pelli-Robson Chart is a 26-alternative forced-choice test with letters as the targets.

Intercorrelations

For a contrast sensitivity test to be valid, we would expect it to be related to other tests of contrast sensitivity. In general, the correlations between pairs of the contrast sensitivity tests administered in this study were moderate to high for the low vision group and low for the soft contact lens group (Table 4). For the soft contact lens group, the low correlations are likely to be the result of a narrow range of test scores. Despite this finding, the correlation coefficients obtained for the low vision group provide some evidence that the tests are valid.

It should be noted that a general limitation of this study includes the use of two different researchers to collect the data, which may have contributed to differences in the reliabilities between the groups. In addition, that the researchers were not masked to the previous test scores may have introduced some bias in the results.

CONCLUSIONS

In general, the 95% LoA were larger for the new versions of the MET and the H/LCVA Chart than for the original versions. This is likely to be the result of the wider increments used for the lower end of the MET scale. For the H/LCVA Chart, this is likely to be because the low contrast letters were 11% compared with 18% Weber contrast. Also, the 95% LoA were larger for the low vision group compared with the soft contact lens group. Moderate to high correlations were obtained between the various contrast sensitivity tests investigated, thus providing evidence of validity. Scores obtained for the new versions of the MET and the H/LCVA Chart were significantly different from the original versions. On average, those with low vision can be expected to score 1.7 dB better on the MET new light box version compared with the original photographic version and 0.13 logMAR worse LCVA on the H/LCVA Chart new printed version compared with the original version. When testing young soft contact lens wearers, on average, the LCVA score using the H/LCVA Chart new printed version can be expected to be 0.08 logMAR worse than with the original version. Considering the range of test scores obtained and the 95% LoA, the MET original version and the Pelli-Robson Chart are most appropriate for assessing contrast sensitivity in those with low vision. For young soft contact lens wearers with normal vision, the H/LCVA original version (18% Weber) and the Pelli-Robson Chart are most appropriate.

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Sharon A. Haymes
Department of Optometry and Vision Sciences
The University of Melbourne
Cnr Cardigan and Keppel Sts
Carlton VIC
Australia 3053
s.haymes@optometry.unimelb.edu.au