The Letter Contrast Sensitivity Test: Clinical Evaluation of a New Design

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Purpose. To compare the reliability, validity, and responsiveness of the Mars Letter Contrast Sensitivity (CS) Test to the Pelli-Robson CS Chart.

Methods. One eye of 47 normal control subjects, 27 patients with open-angle glaucoma, and 17 with age-related macular degeneration (AMD) was tested twice with the Mars test and twice with the Pelli-Robson test, in random order on separate days. In addition, 17 patients undergoing cataract surgery were tested, once before and once after surgery.

Results. The mean Mars CS was 1.62 log CS (0.06 SD) for normal subjects aged 22 to 77 years, with significantly lower values in patients with glaucoma or AMD ($P < 0.001$). Mars test–retest 95% limits of agreement (LOA) were ±0.13, ±0.19, and ±0.24 log CS for normal, glaucoma, and AMD, respectively. In comparison, Pelli-Robson test–retest 95% LOA were ±0.18, ±0.19, and ±0.33 log CS. The Spearman correlation between the Mars and Pelli-Robson tests was 0.83 ($P < 0.001$). However, systematic differences were observed, particularly at the upper-normal end of the range, where Mars CS was lower than Pelli-Robson CS. After cataract surgery, Mars and Pelli-Robson effect size statistics were 0.92 and 0.88, respectively.

Conclusions. The results indicate the Mars test has test–retest reliability equal to or better than the Pelli-Robson test and comparable responsiveness. The strong correlation between the tests provides evidence the Mars test is valid. However, systematic differences indicate normative values are likely to be different for each test. The Mars Letter CS Test is a useful and practical alternative to the Pelli-Robson CS Chart. (*Invest Ophthalmol Vis Sci.* 2006;47:2739–2745) DOI:10.1167/iovs.05-1419

Contrast sensitivity (CS) is a fundamental aspect of vision. Its measurement provides useful independent information in relation to a patient's visual function, which may not be revealed by visual acuity (VA).[1–5] There is considerable evidence that it is a strong predictor of real-world performance, providing insight into a patient's disability and quality of life.[6] Specifically, studies have shown a significant relationship between CS and driving performance,[7] mobility and walking speed,[8] postural stability and falls,[9,10] face recognition,[11] reading speed,[12,13] computer task accuracy,[14] and ability to perform activities of daily living.[15,16] Furthermore, there is evidence to suggest that CS measurement may have some value in the detection and progression of ocular diseases, such as cataract,[17] glaucoma,[2,18] age-related macular degeneration (AMD),[19,20] diabetic retinopathy,[21] and optic neuritis.[22] CS tests have been useful for evaluating cataract surgery,[23] YAG laser capsulotomy,[24] intraocular lenses,[25,26] medications and surgery for glaucoma,[27,28] verteporfin and radiation therapy for AMD,[29] laser photocoagulation and pharmaceutical therapeutics for diabetic retinopathy,[30,31] contact lens use,[32] and laser refractive surgery.[33] Thus, the measurement of CS has substantive importance and value in vision research and clinical care.

Several CS tests with good psychometric properties have been developed that are easily administered in a clinical setting.[6,34] They have been used in numerous clinical research studies and have become standard in low-vision care. The most widely used test is the Pelli-Robson CS Chart.[35] Briefly, it is a large wall-mounted chart, with letters of a fixed size (comprising spatial frequencies appropriate for estimating peak CS) that decrease in contrast. Recently, a similar, portable test called the Mars Letter CS Test has been developed,[36] facilitating convenient administration and out-of-clinic testing. Another advantage is that its termination and scoring rules are simple and unambiguous, whereas various rules have been applied to the Pelli-Robson test, with no established standard.[36] Perhaps the most important new design feature of the Mars test is the use of a finer contrast scale. Contrast changes by 0.04 log units with the Mars test, compared with 0.15 log units with the Pelli-Robson test. The finer scale of the Mars test may result in lower variability,[36] and hence, improved test–retest reliability,[37] and accuracy.[35,38] Indeed, in computer simulations, the Mars test has been shown to have lower variability than the Pelli-Robson test.[36] However, these potential advantages of the Mars test have not been confirmed by sufficient empiric study. We are aware of only one recent publication in which findings for normal subjects and a heterogeneous low-vision group were reported.[39]

The central objectives of this study were to acquire empiric data and to evaluate the psychometric properties of the Mars test in a clinical sample. Our more specific objectives were to determine its discriminability, test–retest reliability and criterion validity for normal subjects compared to patients with glaucoma or AMD, and to determine the responsiveness of the test to cataract surgery.

Methods

Subjects

The sample contained 47 normal control subjects, 27 patients with open-angle glaucoma, 17 with AMD, and 17 undergoing cataract surgery. Control subjects were recruited by placement of a study information sheet on hospital notice boards and patient groups were recruited from the Eye Care Centre, Queen Elizabeth II Health Sciences Centre (Halifax, NS, Canada). Inclusion criteria for the control subjects

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were normal results in an ocular examination and VA better than 0.30 logMAR (20/40). For patients with glaucoma, the inclusion criteria were a glaucoma specialist's diagnosis of open-angle glaucoma, characteristic glaucomatous optic disc (e.g., notching or progressive thinning of the neuroretinal rim), and visual field impairment detected with the Humphrey Field Analyzer (HFA). For patients with AMD, the inclusion criteria were characteristic macular changes with fluorescein angiography (e.g., drusen, retinal pigment epithelium abnormalities, choroidal neovascularization, subretinal hemorrhage, or fibrous tissue),[40] and stable disease (as indicated by ophthalmoscopy and a difference in VA of $<$ 0.20 logMAR at the first study visit compared with a clinic visit at least 1 month before participation). For patients undergoing cataract surgery, the inclusion criterion was lens opacification equal to or worse than grade II (Lens Opacities Classification System II [LOCS II]).[41] To determine eligibility, a full ocular examination was performed, and the medical history was recorded for all subjects. Exclusion criteria were concomitant ocular disease, lens opacification worse than grade II[41] (except for the cataract surgery group), and VA worse than 1.60 logMAR (20/800).

The study design and protocol were approved by the Institutional Ethics Review Board and adhered to the tenets of the Declaration of Helsinki. Subjects gave informed written consent before participation.

Contrast Sensitivity Measures

All subjects were tested with the Mars Letter CS Test (Mars Perceptrix, Chappaqua, NY; http://www.marsperceptrix.com/; previously supplied as the Lighthouse Letter CS Test), a portable chart measuring 23 $\times$ 36 cm, and intended for use at 50 cm.[36] The Mars test has several design principles in common with the Pelli-Robson test. There are eight rows of letters, with six Sloan[42] letters per row. Letters of constant size are used, which decrease in contrast across and down the chart, and the scale is in units of $\log_{10}$ CS (CS = 1/[contrast$_{Weber}$]; contrast$_{Weber}$ = [$L_{background} - L_{letter}$]/$L_{background}$; L, luminance). The Mars test letters subtend 2° (at 50 cm), the change in contrast between successive letters is 0.04 log units (10%), and the range is from 0.04 to 1.92 log CS. To score the test, a value of 0.04 log CS is given per letter named correctly. Three chart forms are supplied, each with a different letter sequence. The charts are printed on sheets of resin-coated paper, using half-tone screening methods, and separately mounted.

Subjects were also tested with the Pelli-Robson CS Chart (Haag-Streit UK, Essex, UK). It measures 59 $\times$ 84 cm in size and at the recommended 1-m test distance, all letters subtend 2.8°. Each of the eight rows comprises two triplets of letters. The three letters within each triplet have equal contrast; however, each triplet decreases in contrast across and down the chart. The change in contrast between successive triplets is 0.15 log units (41%), and the range is from 0.00 to 2.25 log CS. The scoring rule recommended by the manufacturer is the log CS of the last triplet for which two letters (two of three), are named correctly. However, this is not an established standard, and various rules have been applied to the Pelli-Robson test.[36] Assigning a value of 0.05 log CS per correct letter has been shown to improve accuracy and reliability,[36,38] and this scoring rule is used regularly. Two chart forms are provided and are printed by using methods similar to those used for the Mars test.

Testing Procedures

In the normal control group, one eye was randomly selected for study. For the glaucoma and AMD groups, the eye with worse HFA mean deviation or VA, respectively, was selected. The study eye was tested twice with the Mars test and twice with the Pelli-Robson test, in random order. The median time between the test and the retest session was 7 days. As differences between available charts and forms were determined to be nonsignificant in a pilot study ($P > 0.05$), one chart or form of each test was used (chart 1). Background chart luminance was within the range recommended by each manufacturer (Mars test, 113 cd/m^2; Pelli-Robson test, 120 cd/m^2).

For both tests, subjects were instructed to begin reading the letters at the top of the chart and to continue reading across and down the chart. The Mars test was terminated when two consecutive letters were named incorrectly,[36] and the Pelli-Robson test when two of three letters were named incorrectly.[35] Subjects were encouraged to observe letters for at least 20 seconds, as this is often necessary for perception at threshold.[38] Subjects were also encouraged to guess. Although accepting a response of "O" for a presented "C" has been suggested,[43] this method was not applied in our study. Both tests were scored using the letter-by-letter method,[38,44] where a value of 0.04 log CS and 0.05 log CS was given per correct letter for the Mars and Pelli-Robson tests, respectively.

The responsiveness of the Mars and Pelli-Robson tests to cataract surgery was evaluated by testing patients once before surgery and once after surgery (median time before surgery, 2 days; median time after surgery, 8 weeks). The tests were administered and scored for this group in the same manner as described earlier. All cataract patients underwent small-incision phacoemulsification in the study eye, with implantation of a monofocal posterior chamber intraocular lens, by the same surgeon.

For all subjects, distance VA was also tested at each study session, using the Early Treatment Diabetic Retinopathy Study (ETDRS) logMAR chart,[45] with background luminance in the recommended range,[46,47] a termination rule at four of five letters named incorrectly,[48] and letter-by-letter scoring. All tests were performed with optimal spectacle refractive error correction.

Data Analysis

Data were analyzed on computer (SPSS, 12.0 for Windows; SPSS Inc., Chicago, IL). Mars test and Pelli-Robson test descriptives were calculated, and analysis of variance (ANOVA) was used to evaluate the significance of group differences. Linear regression analysis was used to evaluate the relationship between age and each CS test. Spearman's rank correlation coefficient was used to determine the association between Pelli-Robson CS and Mars CS. All analyses were two-tailed and $P < 0.05$ was considered statistically significant.

Test–retest reliability was determined by Bland-Altman analysis.[49] Specifically, we evaluated plots of the difference between the test–retest CS against the mean of the test–retest CS, and the test–retest 95% limits of agreement (LOA; where 95% LOA = mean test–retest difference $\pm$1.96 SD). Differences in 95% LOA between tests were evaluated using F-tests. Responsiveness was investigated by comparing the mean change in scores (difference in pre- and postsurgery CS) and effect size (ES) statistics for the Mars and Pelli-Robson tests. ES statistics are expressions of the magnitude of change in terms of standard units of test variability (SD units) and thereby facilitate comparisons between tests. We selected the Cohen's *d* ES statistic for this study,[50] as it is well-established and there are guidelines for comparing results.[51] Cohen's *d* ES was calculated as follows: ES = (mean CS$_{postsurgery}$ − mean CS$_{presurgery}$)/SD$_{pooled}$. Cohen has suggested that ES statistics of 0.2, 0.5, and 0.8, represent small, medium, and large effects, respectively.[50]

Results

Subject Characteristics

Descriptive statistics for the characteristics of each subject group are given in Table 1.

Descriptives and Normative Data

The Mars and Pelli-Robson tests were both appropriate for use with all subject groups, with no upper or lower end-of-scale limitations. For the normal control group, mean results with the Mars and Pelli-Robson tests were 1.62 log CS (0.06 SD) and 1.79 log CS (0.11 SD), respectively. There was a significant decrease in both Mars CS and Pelli-Robson CS with age (slope of fitted regression line = 0.012 and 0.028 log CS units per decade [R^2 = 0.17 and 0.22, P = 0.004 and 0.001], for Mars CS and Pelli-Robson CS, respectively; Fig. 1). The Mars test prediction interval (Fig. 1) suggests that, for a person aged 25

TABLE 1. Subject Characteristics by Group

Characteristic	Normal Control (n = 47)	Glaucoma* (n = 27)	AMD (n = 17)	Cataract† (n = 17)
Age (y)				
Mean (SD)	48 (17)	67 (11)	73 (7)	73 (8)
Range	22 to 77	41 to 89	58 to 83	58 to 85
Gender				
Male:female	22:25	10:17	6:11	9:8
Best VA, logMAR				
Mean (SD)	−0.02 (0.09)	0.04 (0.11)	0.82 (0.51)	0.45 (0.32)
Range	−0.18 to +0.24	−0.16 to +0.34	0.16 to 1.62	0.02 to 1.40

* Mean Humphrey Field Analyzer mean deviation, −6.42 dB (7.96 SD; range, −31.09 to +1.47).
† VA before surgery.

years, the upper and lower limits of normal Mars CS were approximately 1.72 and 1.56 log CS, respectively. For a person aged 60 years, the upper and lower limits of normal Mars CS were approximately 1.68 and 1.52 log CS, respectively.

Mean CS with the Mars test and the Pelli-Robson test for each group is given in Table 2. The difference between groups was statistically significant with both tests (Mars test ANOVA $F_{2,88} = 56.5$, $P < 0.001$; Pelli-Robson test ANOVA $F_{2,88} = 59.0$, $P < 0.001$).

Test–Retest Reliability

Measures of test–retest reliability are presented in Table 3. The Mars mean test–retest difference for the normal control group was 0.02 log CS (0.07 SD), indicating a small learning effect.

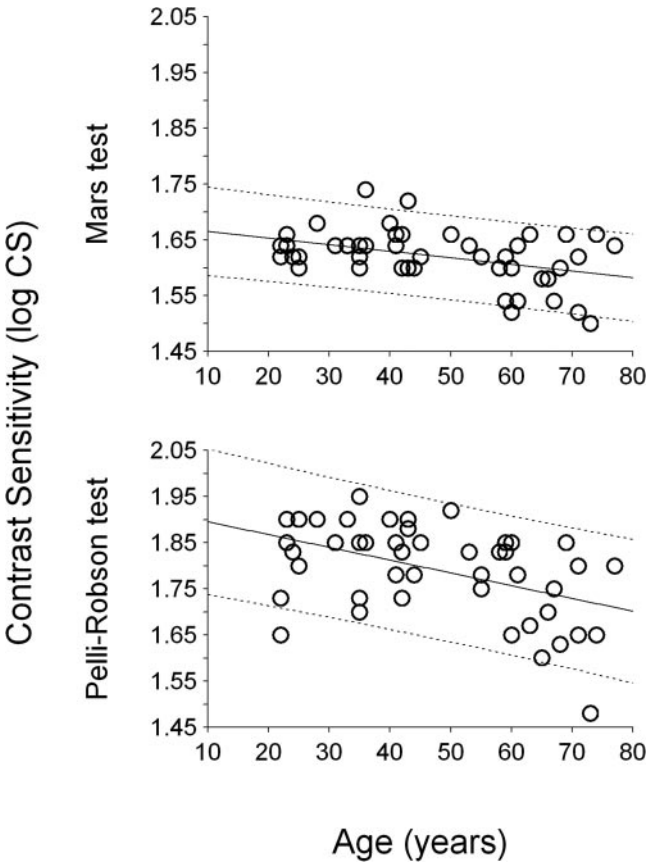

FIGURE 1. Relationship between age and CS, with the Mars (*top*) and the Pelli-Robson (*bottom*) tests, for the normal control group (n = 47). *Solid line*: fitted linear regression (Mars log CS = −0.0012 · age + 1.68 [R^2 = 0.17, P = 0.004]; Pelli-Robson log CS = −0.0028 · age + 1.92 [R^2 = 0.22, P = 0.001]); *dashed lines*: 90% prediction interval.

Similarly small mean test–retest differences were observed with both the Mars and Pelli-Robson tests for all groups (mean test–retest difference ≤ 0.02 log CS, $P > 0.05$); the only exception being for the AMD group with the Mars test (mean test–retest difference = 0.11 log CS, 95% CI, 0.04–0.17 log CS; $t = 3.66$, $P = 0.002$).

The 95% LOA were the same or narrower (lower test–retest variability) with the Mars compared to the Pelli-Robson test, for all groups (Table 3). For the normal control group, the 95% LOA were ±0.13 log CS with the Mars test compared with ±0.18 log CS with the Pelli-Robson test (F-statistic = 1.91, P = 0.03). Comparing the subject groups, the 95% LOA were narrowest for the normal control group, followed by the glaucoma group and widest for the AMD group (Table 3). The increased test–retest variability of patients with AMD compared with the normal control subjects, was statistically significant with both the Mars and the Pelli-Robson tests (F-statistic = 3.62 and 3.39, respectively, $P < 0.005$). The test–retest difference as a function of the test–retest mean is presented in Figure 2, for each CS test and each group. The mean test–retest differences and 95% LOA from Table 3 are indicated on each plot. In all cases, test–retest differences did not vary in a systematic manner over the CS range measured (Fig. 2).

Comparison of Mars Contrast Sensitivity and Pelli-Robson Contrast Sensitivity

The correlation between Mars and Pelli-Robson CS for subjects in the normal control, glaucoma, and AMD groups combined was strong (Spearman's $r = 0.83$, $P < 0.001$). Even so, there were systematic differences between the tests, as indicated by a plot of the difference between the tests as a function of Pelli-Robson CS (Fig. 3). The data do not form a horizontal band across the measurement range. In particular, the difference between Mars CS and Pelli-Robson CS was greater at the upper "normal" end compared with the lower end of the measurement range, where Mars CS was less than Pelli-Robson CS. Both CS tests correlated moderately with ETDRS VA (Spearman's r = −0.64 and −0.68, with the Mars test and Pelli-Robson test, respectively; $P < 0.001$).

TABLE 2. Mean Contrast Sensitivity with the Mars Test and Pelli-Robson Test by Group

Test	Normal Control (n = 47)	Glaucoma (n = 27)	AMD (n = 17)
Mars, log CS			
Mean (SD)	1.62 (0.06)	1.56 (0.15)	1.03 (0.43)
Range	1.44–1.84	0.96–1.76	0.04–1.44
Pelli-Robson, log CS			
Mean (SD)	1.79 (0.11)	1.64 (0.21)	0.98 (0.53)
Range	1.45–1.95	1.05–2.00	0.00–1.60

TABLE 3. Test–Retest Reliability of the Mars Test and Pelli-Robson Test by Group

Test	Normal Control (n = 47)	Glaucoma (n = 27)	AMD (n = 17)
Mars, log CS			
Mean test-retest diff. (SD)*	0.02 (0.07)	−0.01 (0.10)	0.11 (0.12)
Test–retest 95% LOA (±1.96 SD)	0.13	0.19	0.24
Pelli-Robson, log CS			
Mean test-retest diff. (SD)*	0.02 (0.09)	0.01 (0.10)	0.00 (0.17)
Test–retest 95% LOA (±1.96 SD)	0.18	0.19	0.33

* Test CS subtracted from retest CS, such that a positive value indicates an improvement in CS on retest, and a negative value indicates a worsening.

Test Responsiveness

After cataract surgery, mean improvement in best spectacle-corrected VA was 0.39 logMAR (0.33 SD; range, 0.00–1.28 logMAR), with 15 (88%) of 17 patients improving by >0.10 logMAR. Change scores after cataract surgery and ES statistics for the Mars and Pelli-Robson tests are given in Table 4. Mean CS change after cataract surgery was 0.21 (0.27 SD) and 0.24 log CS (0.31 SD) with the Mars and Pelli-Robson test, respectively. Although the mean change was slightly smaller with the Mars than with the Pelli-Robson test, lower variability resulted in a slightly larger ES statistic (0.92 and 0.88, respectively).

DISCUSSION

CS is important because it provides valuable information, independent of VA. Furthermore, it is an important predictor of

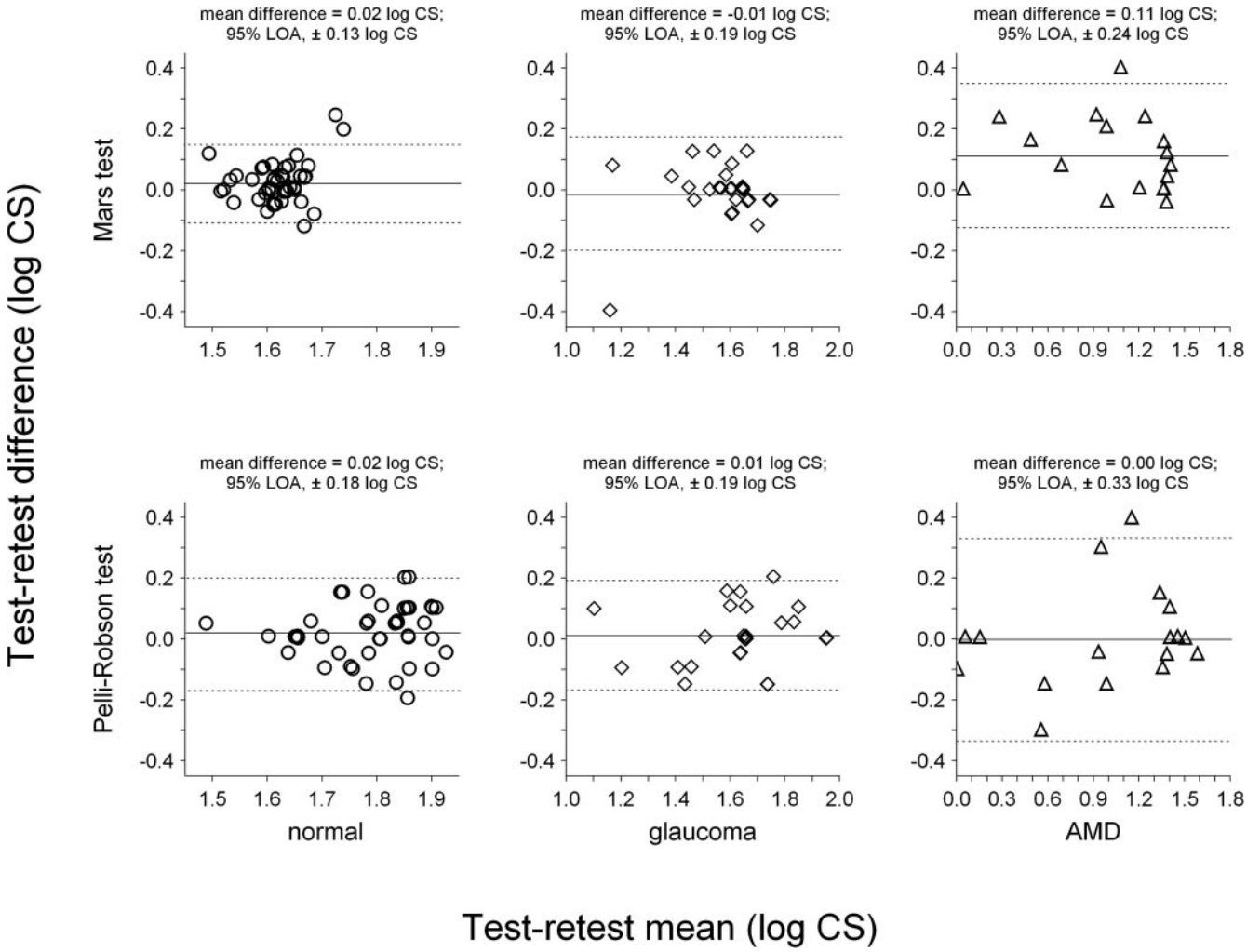

FIGURE 2. Difference between the test–retest CS plotted against mean of the test–retest CS, for the Mars test (*top row*) and the Pelli-Robson test (*bottom row*), for the normal control (*left*; n = 47), glaucoma (*middle*; n = 27) and AMD (*right*; n = 17) groups. All differences are test log CS subtracted from retest log CS. A small amount of noise was applied to allow overlapping data points to be differentiated. *Solid line*: mean of the test–retest differences; *dashed lines*: test–retest 95% limits of agreement (LOA, where 95% LOA = mean test–retest difference ±1.96 SD). To facilitate comparisons, the *y*-axis scale is the same in all graphs. However, because of widely different ranges, the *x*-axis for each group is scaled independently to show the data with clarity.

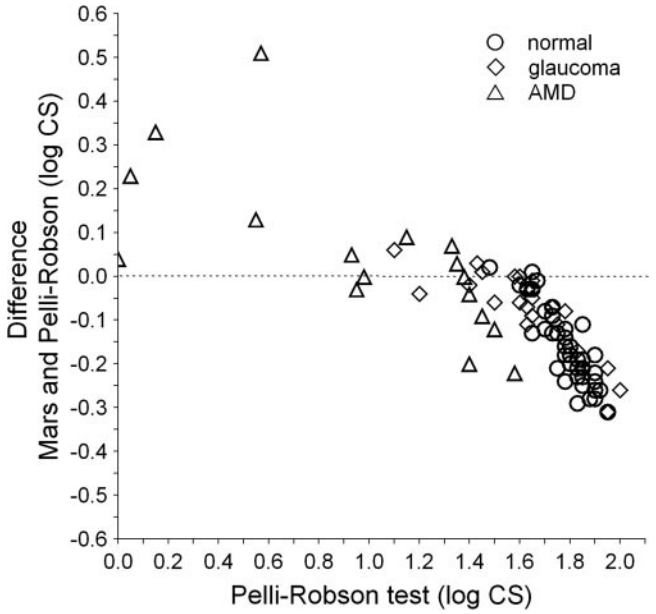

FIGURE 3. Comparison between Mars and Pelli-Robson CS. Difference between Mars and Pelli-Robson CS as a function of Pelli-Robson CS for normal control (n = 47), glaucoma (n = 27), and AMD subjects (n = 17). All differences are Mars log CS minus Pelli-Robson log CS. Each data point was calculated by using the mean of the test and retest CS scores. *Dashed line*: equality.

real-world performance and may be useful for monitoring ophthalmic treatment and detecting disease.[6] Therefore, it is imperative that we have convenient tests with good psychometric properties for measuring CS. A new test, the Mars Letter CS Test, has been designed to improve on the reliability and practicality of current tests, in particular the well-established Pelli-Robson test. In this study, we evaluated the properties of the Mars test (discriminability, test–retest reliability, criterion validity, and responsiveness) in a sample of normal control subjects and patients with glaucoma, AMD, or cataract. Data from the normal control subjects were also used to establish reference values.

Mean Mars CS was 1.62 log CS (0.06 SD), for our sample of normal subjects aged 22 to 77 years. As expected from other studies of the CS function[52,53] and letter CS,[3,4,54,55] we found a small, but statistically significant decrease in Mars CS with age, of 0.012 log CS units per decade (P = 0.004). This decline was less than that for Pelli-Robson CS (0.028 log CS units per decade, P = 0.001). Also, the Mars test was able to discriminate between different patient groups. Compared with normal subjects, Mars CS was lower for patients with glaucoma or AMD (mean Mars CS = 1.62 [normal], 1.56 [glaucoma], and 1.03 log CS [AMD]; $P < 0.001$). These group differences with the Mars test were comparable to those obtained with the Pelli-Robson test (mean Pelli-Robson CS = 1.79 [normal], 1.64 [glaucoma], and 0.98 log CS [AMD]).

To evaluate the consistency of our findings, there are several studies that have provided normative data for the Pelli-Robson test,[1,3–5,39,54,56–60] with which we can make comparisons. In general, our results are consistent with those that used similar methods. For example, Elliott and Bullimore found mean Pelli-Robson CS was 1.83 log CS (0.14 SD) for normal subjects,[57] slightly greater than our finding of 1.79 log CS (0.11 SD). The small difference is likely to be because on average, their sample was younger than our sample. Lovie-Kitchin and Brown[3] found the reverse, a slightly lower value (mean Pelli-Robson CS = 1.74 log CS), possibly because the test was administered at 3 m rather than at 1 m and because the habitual rather than the optimal refraction was used. During the review of this article, a recent clinical study comparing the Mars test and Pelli-Robson test was also published.[39] Compared with our results, Dougherty et al.[39] found a lower mean Pelli-Robson CS of 1.70 log CS for their sample of normal subjects. Again, this may be because the habitual refraction was used, whereas we used the optimal refraction. For the Mars test, mean CS was 1.72 log CS (0.07 SD) in their study,[39] somewhat higher than our finding of 1.62 log CS (0.06 SD). The reason for this difference is unclear. We would have expected mean Mars CS to be lower rather than higher when using the habitual refraction. A possible explanation is that they accepted "C" and "O" miscalls,[39] whereas we did not accept any miscalls.

Mars test–retest 95% LOA were ±0.13 log CS for the normal control group in this study, suggesting that a significant change based on actual scale values would be ±0.16 log CS (four letters). As hypothesized, the 95% LOA for the normal subjects indicate that the Mars test was somewhat less variable (or more reliable) than the Pelli-Robson test (95% LOA = ±0.13 and ±0.18 log CS, with the Mars and Pelli-Robson test, respectively; P = 0.03). This finding is supported by previous studies of the Pelli-Robson test, where test–retest reliability has been found to be in the range of ±0.15 to ±0.20 log CS in normal subjects.[3,38,54,57,61] Furthermore, Dougherty et al.[39] found a similar difference between Mars and Pelli-Robson test–retest reliability in their sample of normal subjects (95% LOA = ±0.14 and ±0.18 log CS, with the Mars and Pelli-Robson test, respectively; after correction for the differences in the Mars chart forms used). We also found that the reliability of the Mars test was equal to or better than that of the Pelli-Robson test in the patient groups (glaucoma and AMD; Fig. 2), which is consistent with results for a heterogeneous group of low-vision patients.[39] We suggest that the improved reliability of the Mars test over the Pelli-Robson test is most likely due to the incorporation of a finer contrast scale.

The 95% LOA found in this study also suggest that test–retest reliability is worse in those with glaucoma or AMD than in normal subjects (Fig. 2), with patients with AMD having the

TABLE 4. Responsiveness of Mars Test and Pelli-Robson Test to Cataract Surgery

Test	Postsurgery Mean (SD) Log CS	Presurgery Mean (SD) Log CS	Change Score* Mean (SD) Log CS	Effect Size (95% CI)†
Mars	1.53 (0.08)	1.32 (0.31)	0.21 (0.27)	0.92 (0.20–1.61)
Pelli-Robson	1.57 (0.13)	1.33 (0.37)	0.24 (0.31)	0.88 (0.16–1.56)

n = 17.

* Presurgery CS subtracted from postsurgery CS, so that a positive value indicates an improvement after surgery, and a negative value indicates a worsening. P = 0.01 and 0.02 for Mars and Pelli-Robson test, respectively.

† Effect size: Cohen's d = (mean $CS_{postsurgery}$ − mean $CS_{presurgery}$)/SD_{pooled}; where $SD_{pooled} = \sqrt{([SD_{postsurgery}^2 + SD_{presurgery}^2/2)}$.

lowest reliability of the three groups (Mars test 95% LOA = ±0.24 log CS; Pelli-Robson 95% LOA = ±0.33 log CS). This finding is supported by several other studies of CS,[39,58,62,63] and studies of VA,[63–66] in which poorer test–retest reliability has been found for samples comprising vision-impaired patients. For example, Haymes and Chen[62] found Pelli-Robson test–retest 95% LOA were ±0.18 log CS and ±0.25 log CS for normal subjects and low-vision patients, respectively.

The strong correlation found between the Mars test and the Pelli-Robson test in this study provides evidence that the Mars test is valid (Spearman's $r = 0.83$, $P < 0.001$). However, systematic differences between the Mars test and the Pelli-Robson test were observed (Fig. 3). At the upper-normal end of the range, Mars CS was less than Pelli-Robson CS and, conversely, Mars CS was greater than Pelli-Robson CS at the lower end of the range. Contrary to this, a difference between the Mars test and Pelli-Robson test was not observed in Arditi's Monte Carlo computer simulation study of the upper range, in which the Mars test had almost negligible bias relative to the Pelli-Robson test.[36] Indeed, our clinical findings do not support his suggestion that scores between the two tests and with published norms for the Pelli-Robson test are directly comparable. With regard to the lower range, there is evidence to support our finding that Mars CS measures were greater than Pelli-Robson CS measures for subjects with poorer CS.[39] However, it should be noted that the samples of subjects investigated with poorer CS have been small.

Our findings indicate that there are differences in CS measurements obtained with the Mars test and the Pelli-Robson test. Given the similarity of the test designs, we suggest that the differences are most likely due to discrepancies in the actual contrast levels. Letter contrast in the midrange has been measured and found to be on average 0.07 log units higher than the stated value for the Mars test, but within 0.02 log units of the stated value for the Pelli-Robson test,[39] providing support for this hypothesis. However, it is difficult to verify the contrast levels of letters in the normal CS range.[67]

As expected, Mars CS improved after cataract surgery (mean change score = 0.21 log CS; 0.27 SD). The ES statistic for the Mars test was 0.92 (95% CI, 0.20–1.61), suggesting a large effect and good responsiveness.[50] In comparison, the Pelli-Robson ES statistic was slightly lower, 0.88 (95% CI, 0.16–1.56). The ES statistic is equal to the magnitude of change divided by the test variability, and although CS with the Mars test changed less, lower variability resulted in a larger ES statistic compared with the Pelli-Robson test ($SD_{pooled} = 0.23$ and 0.28 log CS with the Mars and Pelli-Robson test, respectively). Nevertheless, the small difference between tests is unlikely to be clinically important.[50]

This clinical study has shown that the reliability, validity, and responsiveness of the new Mars Letter CS Test are at least equal to those of the Pelli-Robson CS Chart. However, we found systematic differences between Mars CS and Pelli-Robson CS, indicating that normative values are likely to be different for each test. Although we provide data from a group of normal control subjects for reference, we propose that normative values may have to be established from a larger sample. The Mars Letter CS Test is a useful and practical alternative to the Pelli-Robson CS Chart, with broad applicability in clinical research, low vision care, disease monitoring, and outcomes research.

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