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Normative Reference Ranges for Binocular Summation as a Function of Age for Low Contrast Letter Charts

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Abstract

Purpose—Binocular summation (BiS), defined as the superiority of binocular over monocular viewing on visual threshold tasks, is most-often studied in laboratory settings. Few studies have evaluated BiS with readily-available clinical tools. Low contrast acuity (LCA) charts are increasingly popular in clinical research, yet their utility in detecting BiS has not been evaluated.

Methods—129 normal subjects aged 3–85 years were prospectively enrolled, and underwent monocular and binocular testing using 2.5% and 1.25% Sloan LCA charts and Pelli-Robson (PR) contrast sensitivity (CS) charts at an academic institution. Subjects also underwent similar testing with Early Treatment Diabetic Retinopathy Study (ETDRSVA) charts. BiS was calculated as the difference between the better eye and binocular scores.

Results—Monocular and binocular scores decreased with increasing age for all metrics. The mean(±SD) BiS scores for 2.5% and 1.25% Sloan LCA were 6±4.5 and 3±5 letters, respectively. BiS score was 4.5±7 letters for PR charts and 2±3 letters for ETDRS VA. There was a significant effect of age on BiS for the low contrast metrics ($p \leq 0.001$ for all), but not for high contrast ETDRS VA. Linear regression revealed significant associations between increased interocular difference (IOD) in acuity and decreased BiS for all tests, and associations between increasing age and decreased BiS for the LCA tests.

Conclusion—Of the clinical tests evaluated, 2.5% and 1.25% Sloan LCA charts most readily demonstrated BiS in young normal subjects. BiS declined with increasing age and increased IOD. Median values presented in this study may be useful for future clinical studies utilizing LCA.

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Keywords

binocular summation; low contrast acuity; binocularity; binocular inhibition

Introduction

Binocular summation (BiS) is defined as the superiority of binocular over monocular viewing on visual threshold tasks.[1] Over the past four decades, BiS has been well-studied in laboratory settings, and several important details have been elucidated. BiS is most commonly defined as either *BiS = Binocular Score / Better Eye Score* for a linear measurement scale or *Binocular Score – Better Eye Score* for a log measurement scale. Typically, the magnitude of BiS in normal subjects approximates 40% or more on a linear scale (≥0.15 on a log scale).[2,3,4–7] Early studies revealed that BiS is most evident at lower contrast. Advanced age[8] and interocular differences (IOD) in visual acuity (VA) are both known to reduce or abolish BiS. Subjects with significant IODs in VA, either artificially induced by neutral density filters,[9] glare,[10] or due to pathologic states such as unilateral cataract,[11] anisometropia[12] or amblyopia[13] all exhibit decreased or absent BiS.

For large IODs, a destructive neural interaction may occur, which is known as *Binocular Inhibition: Binocular Score – Better Eye Score < 0.* The mechanism of binocular inhibition is not well defined, but is likely related to inter-ocular suppressive mechanisms[4,14] in area V1,[15,16] and most commonly occurs in subjects with large IODs in VA.[17–19]

There are very few studies that evaluated BiS with readily available clinical tools. Most laboratory studies, by design, have assessed binocular summation in normal control subjects under artificial conditions (e.g. haploscopes or with induced interocular differences in acuity) in order to answer basic scientific questions regarding binocular interactions in strabismus and amblyopia. Given the relevance of BiS to a wide range of ocular diseases, including strabismus, and the possibility that it may provide a useful objective measure of binocular visual function,[20,21] a readily available clinical test to assess BiS would be valuable.

In the present study, we investigated the magnitude of BiS in normal control subjects using readily available clinical tests of low contrast acuity (LCA) and contrast sensitivity (CS). The aim of this study was to evaluate four different letter charts of varying type with fixed and variable contrast levels and spatial frequencies to determine which tests most readily reveal BiS in normal subjects. In addition, the role of aging and increased interocular differences was also evaluated.

Methods

This study was approved by the University of California, Los Angeles Institutional Review Board and conformed to the Declaration of Helsinki and requirements of the United States Health Insurance Portability and Accountability act. Subjects were recruited from staff at the Jules Stein Eye Institute, as well as family members of patients seen in the pediatric

ophthalmology and strabismus clinics between the years of 2010–2011. Subjects with any history of eye disease other than refractive error were excluded.

Procedure—High-contrast visual acuity (VA) was tested using the ETDRS protocol with refractive correction.[22] If VA of 0.2 logMAR or better could not be obtained in both eyes with manifest refraction, then subjects were excluded. Binocular alignment was assessed with distance (10 m) and near fixation (20 cm) using cover/uncover and alternate prism cover testing. Subjects were excluded if they manifested any tropia. Each subject was randomly assigned an order (amongst the right eye, left eye, and binocular tests) that was maintained throughout the study for all psychophysical tests. All testing was performed by trained, experienced technicians. For monocular testing, the fellow eye was occluded with an opaque adhesive patch in contact with the skin. The following tests were performed n the following order:

Low Contrast VA (Low Contrast ETDRS chart and Pelli-Robson CS charts)

Low Contrast ETDRS charts (Precision Vision, La Salle, IL) at 2.5% and 1.25% levels were tested using the ETDRS protocol at 3 meters. Low Contrast ETDRS charts have a similar format to the high contrast ETDRS charts (5 letters per line) with each chart corresponding to a different contrast level. The low contrast VA score is the number of letters identified correctly plus 30, with a maximum score of 100 (14 lines). Testing at 2.5% contrast was performed prior to testing at 1.25% contrast. Testing of low contrast VA was performed in a dimly lit room. Pelli-Robson (Haag Streit, UK) charts were also used to test CS at 1 m using the standard protocol and spectacle correction when appropriate. Log CS was identified as the lowest contrast triplet for which the subject was able to identify at least 2 of 3 letters, with a range from 0.00 to 2.25 in 0.15 log unit steps (normal repeatability is 0.15 log units[23]). In addition, letter count was used to describe Pelli-Robson scores and BiS for Pelli-Robson.

High Contrast VA

VA was tested using the ETDRS charts (Precision Vision, La Salle, IL) and protocol[24] at 3 meters. The rationale for adding 30 letters to the maximum score of 70 letters on the ETDRS chart is so that our values can be used to compare to ETDRS scores that were obtained at any testing distance from 1–4 m. For example, in patients with low vision who cannot read any letters on the top line of the chart, they may be moved in to 1 meter, and then no letters are added to the overall score.

Statistical Analysis—Means, medians, and standard deviations for monocular and binocular scores for each of the four visual outcomes were calculated for all patients and for patients in each age group. For monocular values, only data from right eyes were used. The magnitude of BiS was calculated as the difference between the letter score test result and that of the better eye MAR for the letter charts (ETDRS, 2.5% Sloan and 1.25% Sloan). For the Pelli-Robson chart, BiS for log CS was calculated as the difference between the binocular and better eye scores. For the ETDRS and Sloan LCA charts, a difference ≥ 5 letters was considered to indicate binocular summation, and a difference ≤ -5 letters was considered to indicate binocular inhibition. For compatibility with the other tests, the sign of

the difference score obtained from the Pelli-Robson test was reversed; a difference ≥ 3 letters indicated binocular summation, and a difference ≤− 3 letters indicated binocular inhibition.

The different criteria were used for Pelli-Robson because each Pelli-Robson letter accounts for 0.05 logCS while each Sloan letter accounts for 0.02 logMAR/ The distributions of BiS scores for each psychophysical measurement were examined by using histograms and box plots, and assessed using the Shapiro-Wilk test for normality. In addition, mean BiS for each psychophysical measurement was compared by age decade using a Kruskal-Wallis test to evaluate for differences in BiS. Finally, the influence on BiS of age and interocular difference (IOD) in the visual outcome score was explored by using scatter plots with cubic smoothing splines, and assessed by fitting linear regression models with the corresponding covariates of age and IOD identified. Statistical analysis was carried out using JMP software (Cary, NC).

Results

A total of 129 subjects (61% female) were enrolled having the following age distribution: 3–9 years old (n=10 subjects), 10–19 years old (n=10 subjects), 20–29 years old (n=20 subjects), 30–39 years old (n=23), 40–49 years old (n=23), 50–59 years old (n=20), 60 years or older (n=23). Of the enrolled subjects, 61% were female and 39% were male.

Mean monocular and binocular values

The mean and median values, standard deviations and range of values for monocular and binocular values are presented in Table 1 for each age group and each visual outcome.

The overall distribution of BiS scores for the entire study population is presented in Figures 1A–1D. Figure 2 depicts the distribution of BiS for each age group by decade. Kruskal-Wallis analysis revealed significant differences in BiS with different age groups for 2.5% and 1.25% Sloan LCA charts, and for the Pelli-Robson chart (p=0.001, <0.0001, and 0.006 respectively), but not for high contrast ETDRS VA (p=0.3). In general, scores increased over the first three decades of life and then began to decrease at the fifth decade.

The mean(±SD) BiS score for the 2.5% and 1.25% Sloan LCA charts was 6±4.5 and 3±5 letters, respectively. BiS score was 4.5±7 letters for PR charts and 2±3 letters for ETDRS VA. Table 2 depicts the mean and median values for the BiS for each age group. The measured BiS was apparently greater for 2.5% LCA and 1.25% LCA than for the high contrast ETDRS acuity.

The histograms and box plots revealed that the BiS score was not normally distributed for any of the psychophysical tests except for 2.5% LCA (Figures 1A–1D). Shapiro-Wilk p-value=0.2, 0.006, 0.001 and 0.06, for 2.5% LCA, 1.25% LCA, Pelli-Robson and ETDRS VA charts, respectively). The scatter plots with smoothing spline curve suggested that there was a linear trend for decreasing BiS score for 2.5% and 1.25% Sloan LCA charts with increasing age while there was no apparent correlation between BiS score for Pelli-Robson chart and high contrast ETDRS VA with age (Figures 3A–3D). The scatter plots with

smoothing spline curve also suggested that BiS score for each psychophysical measure was decreased with its increasing IOD value, except for the relationship between BiS score for Pelli-Robson chart and IOD for Pelli-Robson chart which could not be reliably evaluated as almost all patients had score of 0 for BiS and IOD for Pelli-Robson chart.

Based on the relationships suggested above, a linear regression model was constructed to evaluate the influence of age and IOD on binocular summation for the four psychophysical tests used in the study. For 2.5% and 1.25% Sloan LCA charts, both age and IOD were included in the linear regression models, while only IOD was included for the linear regression models for ETDRS VA and Pelli-Robson CS. There was a significant association between increased IOD in acuity and decreasing BiS for all four tests except for Pelli-Robson which showed the association between increased IOD and increasing BiS, signifying that as interocular VA difference increases BiS score tends to decrease for visual function tests. For increasing age, there was a significant association with decreased BiS score for 2.5% LCA ($p=0.002$) and 1.25% LCA ($p<0.0001$). Regression coefficients for each linear regression model are depicted in Table 3.

The percentage of subjects demonstrating summation (defined as BiS ≥ 5 letters) was calculated for each age group and is depicted in Table 4. The overall prevalence of BiS≥ 5 letters was 51%, 32%, 26%, and 12% for the 2.5% LCA, 1.25% LCA, Pell-Robson (BiS≥0.15), and ETDRS charts, respectively. The mean±SD value of BiS for those subjects demonstrating BiS was 8.5±3 letters, 9.5±3 letters, 9±4.5 letters, and 7.5±1.5 letters for the 2.5% LCA, 1.25% LCA, Pelli-Robson, and ETDRS charts, respectively. Overall, there was a decrease in prevalence of BiS with increasing age. The percentage of subjects demonstrating inhibition (defined as BiS score ≤ −5 letters) is depicted in Table 5.

Discussion

BiS for visual threshold tasks has interested visual psychophysicists for decades. However, BiS has also garnered further interest amongst clinical ophthalmologists as a metric of binocular function in various ophthalmic diseases.[13,21,25–28] There is great interest into the effect that age, interocular difference, and various ophthalmic disorders may have on BiS, or susceptibility to binocular inhibition.[13,21,25–28] Because BiS is still not a well-understood phenomenon, there are several hypotheses as to its basis. A historical explanation for the √2 approximation for BiS is that the visual system integrates both signal and uncorrelated noise from each eye, resulting in an increase in the signal to noise ratio of v2.[29] While this explanation provided an adequate descriptor for much of the early data on binocular summation, it has been discredited as a rigorous model of binocular summation and fails to address binocular inhibition. The current models proposed by Ding and Sperling[14] and Baker and Meese[30] are two-stage models in which contrast gain control is applied at different stages in the visual pathway, and reciprocal inhibition is also present.

Previous studies evaluating BiS in visually and neurologically normal subjects have shown that for many visual tasks, BiS, when calculated as a ratio, often approximates 1.4.[1,31] The majority of these studies have used laboratory based measures such as forced choice protocols for contrast sensitivity and visual evoked potential. If clinical researchers wish to

study BiS, it would be useful to have easy-to-use and readily available tests. The current study shows that Sloan LCA charts at both 2.5% and 1.25% contrast levels are useful in demonstrating BiS in normal controls, and provide a normative range of BiS values. The mean BiS letter difference scores in the present study were 6 and 3 letters for the 2.5% and 1.25% charts, respectively. These log difference scores correspond to linear binocular summation ratios of 1.29 and 1.14. This differs from our previous study which had a similar mean BiS score for the 2.5% chart (1.3) but not for the 1.25% (1.5).[21] The most likely explanation for this difference is the inclusion of more elderly patients in the current study's normal population, which likely brings the mean score downwards at the lowest contrast level. At the lowest contrast levels, age is a known factor in diminishing BiS and even is associated with binocular inhibition.[8] Of those patients who did demonstrate BiS,the mean score was higher for the 1.25% chart. The Pelli-Robson chart and the high contrast ETDRS chart were not as useful in displaying robust BiS even for the youngest age group. Although we did not expect subjects to demonstrate BiS for the ETDRS chart given its high contrast, we were surprised that the Pelli-Robson contrast threshold chart also failed to demonstrate high BiS in normal subjects. One possible explanation for this finding is that in normal subjects, the threshold for the Pelli-Robson test approximates the minimum contrast value. For this reason, we may be observing a "ceiling effect" that obscures binocular enhancement. Others have suggested that the coarse step sizes on the Pelli-Robson chart may exceed the smaller effects of BiS.[32]

The 2.5% and 1.25% LCA charts were particularly useful in demonstrating BiS. Normal younger subjects could discriminate higher spatial frequencies during binocular than during monocular viewing, so that most subjects had BiS exceeding zero. The mean amount of BiS in our population was similar to that of the largest study of BiS using ETDRS VA, the Los Angeles Latino Eye Study[19], in which the mean BiS was 0.06 (compared to 0.04 logMAR, or 2 letters, in our subjects). As expected, our data for lower contrast charts revealed a higher BiS than for the high contrast ETDRS chart. The 2.5% LCA chart had the highest measured mean BiS of a 6 letter difference. These data suggest that a mean of 6 letters may be expected from healthy normal young subjects when utilizing this LCA test to evaluate BiS. Interestingly, as age increased, the number of subjects exhibiting BiS at low contrast levels decreased, and more binocular inhibition was observed.

It is well known that increasing age is associated with reduced BiS and can be associated with binocular inhibition.[33] In the current study, diminished BiS occurred at two age cut-off points: first at 40 years and then again at 60 years as seen in the Figure 3. Gagnon and Kline have proposed the neural noise hypothesis[2] may explain the age-related decline in BiS. This hypothesis suggests that the summing of both signal and uncorrelated noise between the two eyes produces a √2 neural summation-factor for contrast.[8] An age-related increase in noise might explain this decline in BiS.[8] Additional considerations include age-related neuronal cell loss[34] or increased neural variability.[8,35,36] In addition, despite the fact that our study participants were considered to have healthy and normal visual systems, we still found that they demonstrated small interocular differences in VA. It is likely that these interocular differences may have reduced BiS and promoted inhibition in these subjects.

Although clinical LCA letter charts do not demonstrate BiS as robustly as many laboratory tests, they may be useful as convenient measures of binocular function especially in strabismus patients who cannot achieve stereopsis. In particular, LCA charts reveal an age-related decline in BiS that is most evident at the lowest level of contrast. Patients with binocular inhibition may have binocular visual complaints that are difficult to describe, diagnose and manage. Measurements of low contrast binocular summation and inhibition may inform clinicians as to why certain patients prefer to close one eye in visually demanding situations despite the lack of diplopia. This information may also be useful in a wide range of patient-care scenarios such as strabismus patient surgical management, pre-operative assessment of patients undergoing cataract or refractive surgery to induce monovision, and as a measurement of binocular function in unilateral macular disease.

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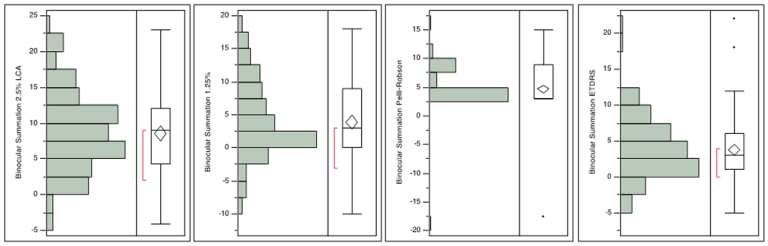

Figure 1. Histogram and outlier box plot depicting the distribution of binocular summation (BiS) for each psychophysical test. A

2.5% Sloan low contrast visual **B**. 1.25% Sloan low contrast visual acuity C. Pelli-Robson BiS contrast D. High contrast ETDRS visual acuity

LCA: low contrast acuity, ETDRS VA: Early treatment diabetic retinopathy study visual acuity

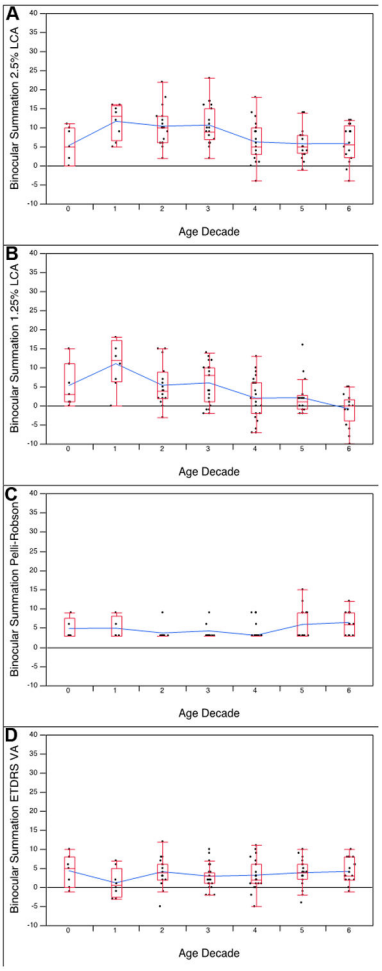

Figure 2. Box-and-whisker plots depicting the effect of age on binocular summation (BiS). Blue line connecting the means for each

Black circles represent data for individual subjects. A. 2.5% Sloan low contrast visual acuity BiS declined significantly with age (p=0.001, Kruskal-Wallis). **B**. 1.25% Sloan low contrast visual acuity BiS declined significantly with age (p<0.0001, Kruskal-Wallis). **C**. Pelli-Robson BiS contrast sensitivity declined significantly with age (p=0.006, Kruskal-Wallis) **D**. High contrast ETDRS visual acuity BiS did not exhibit significant variation with age (p=0.3, Kruskal-Wallis).

LCA: low contrast acuity, ETDRS VA: Early treatment diabetic retinopathy study visual acuity

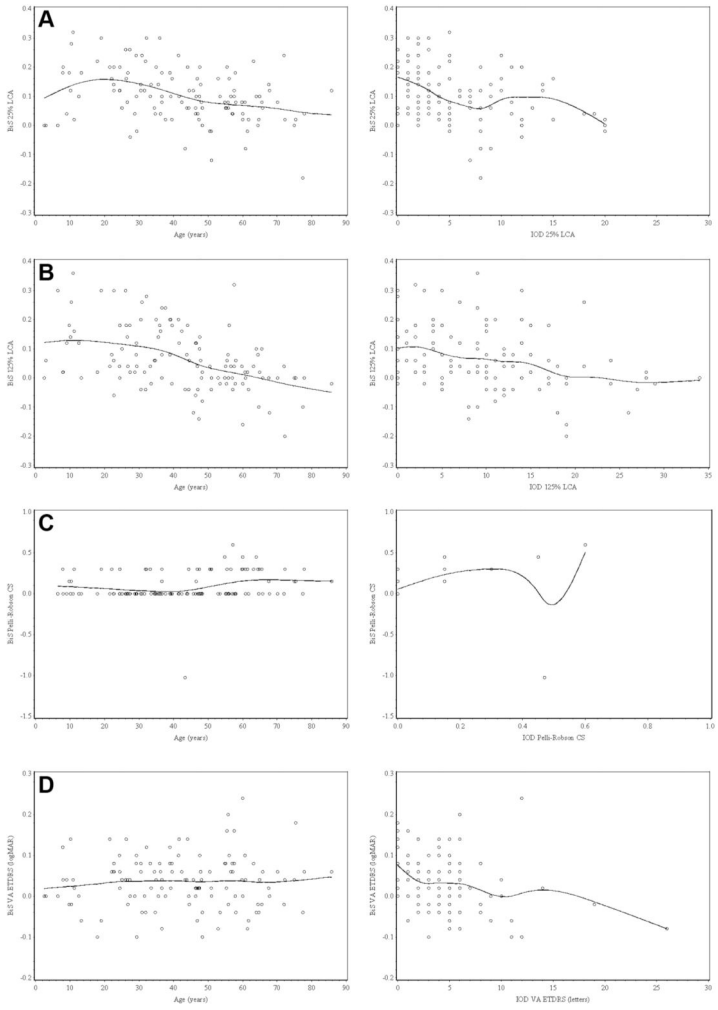

Figure 3. Scatterplots with smoothing spline curve

A. 2.5% Sloan low contrast acuity binocular summation vs age (right) and interocular difference (left). Both plots suggest a linear trend for a decrease in binocular summation with increasing age and interocular difference. **B**. 1.25% Sloan low contrast acuity binocular summation vs age (right) and interocular difference (left). Both plots suggest a linear trend for a decrease in binocular summation with increasing age and interocular difference. **C.** Pelli Robson contrast sensitivity binocular summation vs age (right) and interocular difference (left). There is no apparent correlation between binocular summation score and age or interocular difference (multiple overlapping points displayed as one circle). **D**. ETDRS high contrast acuity binocular summation vs age (right) and interocular difference (left). There is no apparent correlation between binocular summation score and age. There is a linear trend towards decreasing binocular summation score with increasing interocular difference. *LCA: low contrast acuity, ETDRS VA: Early treatment diabetic retinopathy study visual acuity, IOD: interocular difference in visual acuity*

Table 1

Monocular and binocular visual function (mean ± SD, median, range)*

Age (years)	2.5% LCA (letters)	1.25% LCA (letters)	Pelli-Robson (letters)	ETDRS VA (letters)
2–9	OU: 66±8 Median: 70 Range: 47–81 OD: 61±6 Median: 61 Range: 47–74	OU: 49±17 Median: 49 Range: 30–70 OD: 43±13 Median: 43 Range: 30–58	OU: 42±0 Median: 42 Range: 42–42 OD: 40±5 Median: 42 Range: 36–42	OU: 84±7 Median: 54 Range: 74–100 OD: 80±8 Median: 79 Range: 72–95
10–19	OU: 73±5 Median: 71 Range: 65–80 OD: 61±8 Median: 59 Range: 53–73	OU: 65±6 Median: 67 Range: 55–72 OD: 54±7 Median:54 Range: 42–67	OU: 42±0 Median: 42 Range: 42–42 OD: 1.89±5 Median: 42 Range: 36–42	OU: 89±4 Median: 90 Range: 83–93 OD: 88±4 Median: 87 Range: 83–94
20–29	OU: 73±7 Median: 74 Range: 50–84 OD: 62±6 Median: 63 Range: 48–72	OU: 61±7 Median: 62 Range:40–70 OD: 56±6 Median: 59 Range: 39–62	OU: 42±5 Median: 42 Range: 42–2.25 OD: 41.5±5 Median: 42 Range: 36–42	OU: 92±6 Median: 92 Range: 74–100 OD: 88±6 Median: 89 Range: 72–99
30–39	OU: 74±5 Median: 75 Range: 62–81 OD: 63±7 Median: 65 Range: 39–74	OU: 64±6 Median: 64 Range: 52–79 OD: 58±6 Median: 60 Range: 43–70	OU: 42±5 Median: 42 Range: 42–2.25 OD: 41.5±5 Median: 42 Range: 36–42	OU: 94±4 Median: 94 Range: 86–100 OD: 91±5 Median: 93 Range: 79–100
40–49	OU: 69±8 Median: 70 Range: 54–78 OD: 62±8 Median: 65 Range: 45–74	OU: 60±8 Median: 63 Range: 45–74 OD: 58±7 Median: 60 Range: 43–68	OU: 42±0 Median: 42 Range: 42–42 OD: 42.5±9 Median: 42 Range: 36–42	OU: 89±7 Median: 89 Range: 74–98 OD: 85±7 Median: 86 Range: 70–96
50–59	OU: 65±9 Median: 67 Range: 39–75 OD: 59±7 Median: 60 Range: 40–70	OU: 57±8 Median: 59 Range: 38–69 OD: 55±7 Median: 56 Range: 39–64	OU: 42±0 Median: 42 Range: 42–42 OD: 40±7 Median: 42 Range: 36–42	OU: 89±5 Median: 89 Range: 80–97 OD: 85±5 Median: 87 Range: 78–92

Age (years)	2.5% LCA (letters)	1.25% LCA (letters)	Pelli-Robson (letters)	ETDRS VA (letters)
>60	OU 59±10	OU: 48±11	OU: 40±7	OU: 85±6
	Median: 63	Median: 44	Median: 42	Median: 87
	Range: 35–76	Range: 30–65	Range: 33–42	Range: 73–94
	OD: 49±10	OD: 47±11	OD: 37±7	OD: 80±6
	Median: 50	Median: 48	Median: 36	Median: 80
	Range: 30–74	Range: 30–64	Range: 33–42	Range: 58–94

ETDRS VA: Early treatment diabetic retinopathy study visual acuity, LCA: Low contrast acuity; OU: binocular, OD: right eye

* Values based on ETDRS letter score plus 30 letters

Table 2

Binocular summation by age decade (mean ± SD, median, range)

Age (yrs)	2.5% LCA (letters)	1.25% LCA (letters)	Pelli-Robson (letters)	ETDRS VA (letters)
2–9	4.5±4.5 Median 2 Range 0 to 10	5±5 Median 3 Range 0 to 15	5±5 Median 0 Range 0 to 9	1.5±2.5 Median 0 Range -1 to +6
10- 19	10±5 Median 10 Range 1 to 16	10±±5 Median 7.5 Range 0 to 18	5±5 Median 0 Range 0 to 9	-0.25±3.5 Median -0.5 Range -5 to 7
20- 29	5±±4 Median 5 Range -2 to 15	5±4.5 Median 5 Range -3 to 15	2.5±5 Median 0 Range 0 to 9	2.5±2.5 Median 3 Range -5 to 7
30- 39	5±4 Median 7 Range 1 to 15	6±5 Median 7 Range -2 to 15	4.2±5 Median 0 Range 0 to 9	1.5±2.5 Median 2 Range -4 to 6
40- 49	5±3.5 Median 5 Range -4 to 12	1.5±5 Median 2 Range -7 to 10	0±7 Median 0 Range -23 to 9	1.5±3 Median 1 Range -5 to 7
50- 59	4±3.5 Median 4 Range -6 to 10	2±4 Median 1 Range -2 to 16	5±7 Median 0 Range 0 to 15	2.5±3.5 Median 3 Range -4 to 10
>60	3±4 Median 2 Range -9 to 10	-0.5±4 Median 0 Range -1.0 to 5	7±7 Median 7 Range 0 to13	1.5±3.5 Median 2 Range -4 to 12

ETDRS VA: Early treatment diabetic retinopathy study visual acuity, LCA: Low contrast acuity; CS: contrast sensitivity

Table 3

Linear Regression Models for Binocular Summation, and Covariates of Age and Interocular Difference

2.5% LCA	**Regression Coefficient±SE**	**P-value**
Age (years)	−0.001±0.0004	0.002
Interocular difference 2.5% LCA (letters)	−0.005±0.002	0.003
R^2	0.18	

1.25% LCA	**Regression Coefficient±SE**	**P-value**
Age (years)	−0.002±0.0005	<0.0001
Interocular difference 1.25% LCA (letters)	−0.004±0.001	0.001
R^2	0.27	

Pelli-Robson	**Regression Coefficient±SE**	**P-value**
Interocular difference in contrast threshold	0.49±0.13	0.0004
R^2	0.099	

ETDRS VA	**Regression Coefficient±SE**	**P-value**
Interocular difference ETDRS VA (letters)	−0.005±0.001	0.0008
R^2	0.089	

ETDRS VA: Early Treatment Diabetic Retinopathy Study Visual Acuity, LCA: low contrast acuity; SE=Standard error

Table 4

Percentage of subjects demonstrating binocular summation (binocular summation score ≥ 0.1)

Age (years)	n	2.5% LCA	1.25% LCA	Pelli-Robson	ETDRS VA
2–9	10	30%	30%	0	10%
10–19	10	70%	80%	0	10%
20–29	20	70%	40%	0	10%
30–39	23	89%	52%	0	9%
40–49	23	39%	30%	5%	13%
50–59	20	30%	10%	0	15%
>60	23	30%	4%	0	13%

ETDRS VA: Early Treatment Diabetic Retinopathy Study Visual Acuity, LCA: low contrast acuity

Table 5

Percentage of subjects demonstrating binocular inhibition (binocular summation score ≤ −0.1)

Age (years)	n	2.5% LCA	1.25% LCA	Pelli-Robson	ETDRS VA
2–9	10	0	0	0	0
10–19	10	0	0	0	10%
20–29	20	0	0	0	5%
30–39	23	0	0	0	0
40–49	23	0	13%	4%	4%
50–59	20	5%	0	0	0
>60	23	4%	22%	0	0

ETDRS VA: Early Treatment Diabetic Retinopathy Study Visual Acuity, LCA: low contrast acuity