ISSN: 2754-4990

Journal of Ophthalmology Research Reviews & Reports

SCIENTIFIC Research and Community

Review Article

Open Access

Interactive Computer Thresholding of Central Acuity under Conditions of Contrast and Luminance Simulating Real World Environments: Evaluation of the Effects of Aging and Optical Correction

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ABSTRACT

Purpose: The Central Vision Analyzer (CVA) is an interactive computer device that has been reported to measure functional resolution at fixation under contrast and luminance conditions and fixation times which mimic a number of vision tasks of day and evening activities. The program presents Landolt C's that are flashed at fixation for 250 msec and tumbled 1 of 4 directions; the program thresholds for the smallest C the position of which is correctly recognized. In sequential fashion, the CVA tests 3 mesopic environments (98% Michelson Contrast, MC, against a background of 1.6 cd/m2, 25% MC against 5 cd/m2, then 50% MC against 1.6 cd/m2) and 3 glare environments (98%, 10% and 8% MC, all against a background of 220 cd/m2). This report evaluates the impact of aging and optical correction method on the resolution acuity measured in normal eyes.

Methods: The visual acuities measured in normal eyes with the CVA were compared among three age groups: 18-30, 31-50 and 51-65. Comparisons were made between the three age groups in emmetropic eyes and myopic or hyperopic eyes tested with both contact lens and spectacle correction.

Results: In emmetropic eyes, a significant decline was found with aging in both the 25% and 50% MC mesopic modules with a borderline significant change in the 98% MC mesopic module (but greater than the test-retest reliability) while a significant improvement was observed with aging among the myopic eyes, approximately 0.15 logMAR. In both myopic and hyperopic eyes, a small decline in vision of 0.10 to 0.12 logMAR was observed with aging when corrected with contact lenses while with spectacles, visual acuity remained approximately stable, with both corrections producing a similar acuity in the oldest age group.

Conclusions: This study demonstrates changes in the vision measured in real world environments that is associated with aging and appears in line with the reported worsening in lens optical density, retinal sensitivity, and tear film stability that occur with aging. Whether the effects continue to worsen beyond age 65 or change in alternative ways with pathologies associated with aging, remain to be studied.

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Received: January 19, 2022; **Accepted:** January 25, 2022; **Published:** January 29, 2022

Introduction

When measured with distance charts, a number of previous studies have observed no change in high contrast visual acuity at fixation associated with age in healthy eyes up to age 65 and, similarly, no change in contrast sensitivity [1-4]. This is surprising since there is a documented significant increase in lens optical density and a decrease in retinal sensitivity that occurs with aging [5-9]. However, all of these effects may become significant in reducing vision only when lighting and contrast are reduced to critical levels, i.e. in mesopic conditions that are not tested with the relatively well-lit charts in the examining lane. Under such conditions, there is also a decrease in pupillary size with age along with a progression of astigmatic, refractive-index changes within the human lens that may be expected to produce changes in vision [10]. However, again these may become noticeable only when the contrast and luminance of the conditions is sufficiently lowered or glare is sufficiently increased that there is an impact on vision. Adams et al, in a pilot study of 8 patients with a mean age of 57, did observe a decline of two Snellen lines in comparison with younger individuals with a mean age 24.6 when vision was measured under conditions in which the luminance was reduced to 5.4 cd/m2 and the contrast to 10% whereas under conditions

of higher luminance or greater contrast, no differences were observed [11].

We sought to determine if vision testing under stressful mesopic or glare environments with reduced contrasts would reveal changes with age, and furthermore, whether this effect was more pronounced in hyperopic or myopic individuals corrected with spectacles as opposed to contact lenses since this optical correction introduces relatively greater amounts of veiling glare [12,13]. To our knowledge, no studies have evaluated the effect of aging on vision when myopic eyes were examined separately from hyperopic and emmetropic eyes.

Study Conduct

Testing Equipment

The Central Vision Analyzer is an interactive computer program that presents Landolt C's that are flashed at the center of a fixation cross presented on a monitor positioned at 20 feet distance. The C's are flashed for 250 msec against a background pedestal that precedes the C presentation by 300 msec, in order to prevent retinal adaptive persistence of the fixation cross. The duration of the C presentation mimics fixations that have been previously measured for common activities (driving, reading, facial recognition) [13,14]. At each presentation the C is tumbled in one of four positions; the patient responds his or her recognition of the opening position by pressing one of 4 buttons placed in a diamond on the surface of a response pad held in the lap (Figure 1). The method for staircase approach and thresholding using 0.05 logMAR steps has been previously described [14].

Figure 1: Subject holds a response pad with both buttons and joystick that allows response to the tumbled C position presented on the monitor when viewed in a mirror at the end of the room (mirror not shown). Each eye is tested alone with the opposite blocked with a dark patch

All testing with the CVA is conducted in a darkened room (less than 5 cd/m2). In sequential fashion (Table 1), the CVA first tests three mesopic environments (maximal 98% Michelson Contrast, MC, white C's against 1.6 cd/M2 background, then 25% MC against a background of 5 cd/m2 representing observation of facial features while evening dining in a restaurant, then 50% MC against 1.6 cd/M2 background representing the observation of objects while driving at dusk). Together with the relative dark background of the instruction animations and practice test, this allows approximately 1.5 minutes for the subject to adapt to the tested mesopic luminance levels. Three photopic modules are then tested in sequence (98% MC high contrast black C's against 220 cd/M2, then 10% MC against 220 cd/M2, representing playing golf or tennis with the sun overhead and finally 8% MC against 220 cd/M2, representing the same sport but with the sun off-axis creating off-axis glare at 15o). The derivation of the environments and their validation have been described previously [14].

Table 1: Description of the luminance levels (Cd/m2) and Michelson contrasts of the white C presented against the dim/black background in the 3 Mesopic modules (M) and of the black C presented against the white, photopic background in the 3 Photopic modules (P). The simulated vision tasks are also presented

CVA modules		MC Michelson Contrast	Letter	Letter luminance cd/m²	Background luminance cd/m²	Test simulates
1	CVA98% Mes.	98%	White	220	1.6	Mesopic – high contrast
2	CVA25% Mes.	25%	Grey	8.4	5	Mesopic – restaurant dining
3	CVA50% Mes.	50%	Grey	4.8	1.6	Mesopic – driving at dusk
4	CVA98% Pho.	98%	Black	1.6	220	Photopic –high contrast
5	CVA10% Glare	10%	Grey	180	220	Photopic – sun over head while playing golf or tennis
6	CVA8% Glare	8%	Grey	186	220	Photopic - sun 15° off-axis while playing golf or tennis

The monitor luminance and contrasting C's during the CVA testing are controlled using a linear gamma with colorimeter recalibration performed monthly using a Huey Colorimeter and software (Pantone, Carlstadt, NJ). In addition, the luminance of the letters and backgrounds of each CVA module were confirmed using a spot meter (Sekonic L558, Sekonic Industries).

Subjects and Testing Methods

Subjects aged 18 or above with a normal ocular examination were recruited. Normal eyes were defined by an ocular or systemic history lacking abnormalities that were thought to affect vision and by a normal ocular examination utilizing funduscopy performed by 90D biomicroscopy without pupil dilation. The refractive error was required to be within +/-5.00 diopters with astigmatism of less than 1.00 D and with no astigmatism greater then 0.50D or spherical equivalent difference of greater than 1.00D between eyes. Eyes were included if the lens opacity, as defined by the Lens Opacity Classification System III, was less than NO1, NC1 for ages 15-50, less than NO2, NC2 for ages 51-65, and furthermore, if there were no cortical or posterior subcapsular opacity observed within the pupil under dim light [15]. Eyes were excluded if a corneal surface irregularity was detected that was felt to have an impact on vision by producing an aberration of more than 0.4 mm of corneal radius curvature. Tear film stability was assessed by using tear break-up times with a break-up time of 10 seconds or greater considered to be normal[16]. The surface of the contact lens was assessed for deposits, wetting and fit; eyes were excluded if considered not to be within normal limits as defined by Cho et al and Timberlake et al [16,17].

This study also compared the vision measured with the CVA among the hyperopic or myopic eyes with the vision measured in age-matched individuals with emmetropic eyes. Among the persons recruited and measured, the eyes were divided into 1) those with emmetropia, defined as having a refraction between -0.50 D and +0.75 D spherical equivalence with less than ±0.50 D astigmatism, 2) those with myopia (refraction -1.00 D to -5.00 D or spherical equivalent with astigmatism less than 1.00 D), and 3) those with hyperopia (refraction +1.00 D to +5.00 D or spherical equivalent with astigmatism less than 1.00 D). All of the individuals with ametropia who were investigated in this study had worn CL's previously.

Testing with the Central Vision Analyzer was randomized for the eye tested first. In the myopic and hyperopic groups the testing order with CL or spectacles was also randomized. The eyes with myopia or hyperopia underwent testing with the CVA, both with a trial frame containing lenses with anti-reflective coatings and with silicon, hydrogel contact lenses (PureVision, Bausch and Lomb Rochester, NY), conducted with the contact lens vision measured after a half hour of wear and with a break of 30 minutes in between testing sessions. An over-refraction was performed while the patient was wearing the contact lenses in order to determine that there was no residual astigmatism greater than ± 0.25 diopters. The vision measurement, either with the contact lens or with the trial frame, was always with their best refraction.

Statistical Analysis

To evaluate the effects of aging, all subjects were divided into three groups: ages 18- 30, 31-50, and 51-65. For all three age groups the mean and standard deviation of the refractive error were calculated. Comparisons were made of the acuity obtained for each CVA module among the three age groups for each of the three refractive groups utilizing a post-hoc Tukey Test for significance at $p<0.05$ [18]. All statistical analyses were subjected to GEE and GLM model analysis to evaluate the effect on outcomes of utilizing two eyes of an individual, and all statistical results are reported after correction for those effects [19-21]. In addition, among each of the myopic and hyperopic correction groups, we attempted to evaluate a linear regression analysis to examine if there were a relation between the vision measured with each CVA module and age. However, the data, when evaluated by the Kolmogorov-Smirnov Test, was noted to be skewed without sufficient representation among each decade of age. Nevertheless, the data for each CVA module was plotted to examine for the slope and scatter of the acuity over the age ranges studied, in order to evaluate the group comparison results.

Results

Effects of Aging on Vision Measured in Emmetropic Eyes

For each of the age groups among the persons having emmetropic eyes, the mean age is presented in table 2 along with the mean refractive error. No significant differences were noted in the refractive errors among the three age groups as evaluated by Student's t-test.

Table 2: Mean and SD of the refractive error for each age group among the emmetropic eyes

Age Group	SPH	CYL	Mean Age	Eyes (# Patients)
18-30 years	-0.02 (±) 0.15	-0.02 (±) 0.08	24.11 (±) 4.60	56 (28)
31-50 years	-0.06 (±) 0.19	-0.05 (±) 0.15	39.21 (±) 5.04	56 (28)
51-65 years	0.11 (±) 0.32	-0.09 (±) 0.21	54.88 (±) 3.25	50 (25)

The comparison of the vision results for each of the six CVA modules is presented in figure 2 with the statistical comparison presented in table 3. A significant decline in vision with age of 0.12 logMAR was noted in the CVA 98% MC white-on-black, mesopic module between the youngest age group (18-30) and the oldest (51–65) ($p<0.01$).

Figure 2: Mean logMAR visual acuity with 95% confidence interval obtained for each CVA module among the emmetropic eyes

Order of presentation	CVA module	Colour	Michelson contrast	Test simulates
1	CVA 98%M	1	98%	Mesopic - high contrast
2	CVA 25%M	2	25%	Mesopic - restaurant
3	CVA 50%M	3	50%	Mesopic – driving at dusk
4	CVA 10%P	4	10%	Photopic glare – sun over head
5	CVA 8%P	5	8%	Photopic glare – sun 15o off-axis
6	CVA 98%P	6	98%	Photopic glare – high contrast

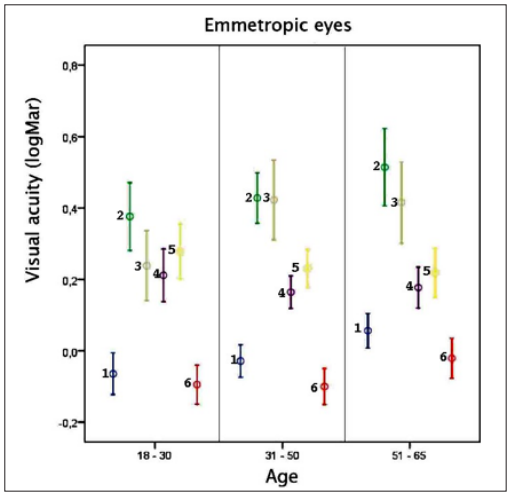

Table 3: Differences and post hoc Tukey test results of VA measured with each CVA module in emmetropic eyes among the three age groups. Differences that are significant (p<0.05) between the age groups are marked in yellow

CVA Module	(I) Age group	(J) Age group	Mean difference (I-J)	Standard error	p value Sig	95%-Confidence Interval VA (LogMAR)	
			LogMAR VA			Lower bound	Upper bound
CVA 98%M	18 - 30	31 - 50	-0.03	0.03	0.57	-0.11	0.04
		51 - 65	-0.12(*)	0.03	<0.01	-0.20	-0.03
	31 - 50	51 - 65	-0.08	0.03	0.06	-0.17	0.00
CVA 25% M	18 - 30	31 - 50	-0.05	0.06	0.69	-0.20	0.09
		51 - 65	-0.13	0.06	0.08	-0.29	0.01
	31 - 50	51 - 65	-0.08	0.06	0.38	-0.24	0.06
CVA 50% M	18 - 30	31 - 50	-0.18(*)	0.07	0.03	-0.36	-0.00
		51 - 65	-0.17	0.07	0.05	-0.35	0.00
	31 - 50	51 - 65	0.01	0.07	0.99	-0.17	0.18
CVA 10% P	18 - 30	31 - 50	0.04	0.04	0.49	-0.05	0.14
		51 - 65	0.03	0.04	0.70	-0.06	0.13
	31 - 50	51 - 65	-0.01	0.04	0.95	-0.11	0.08
CVA 8% P	18 - 30	31 - 50	0.04	0.04	0.56	-0.06	0.15
		51 - 65	0.06	0.04	0.41	-0.05	0.17
	31 - 50	51 - 65	0.01	0.04	0.95	-0.09	0.12
CVA 98%P	18 - 30	31 - 50	0.01	0.03	0.98	-0.08	0.09
		51 - 65	-0.07	0.03	0.13	-0.16	0.01
	31 - 50	51 - 65	-0.07	0.03	0.10	-0.16	0.01

However, no difference was noted at the same high, 98% contrast when presented as a black letter against a white, photopic background. A more significant worsening in acuity was also noted in the low luminance, 50% mesopic module (restaurant dining) of 0.18 log MAR between the age 18–30 group and the 31-50 age group (p = 0.03), with also borderline significance between the 18-30 age group and those aged 51–65 (p=0.05).

When the acuities for the emmetropic eyes were plotted against the age for each CVAmodule, all plots appeared to graphically support the conclusions demonstrated above, namely a near flat slope of the acuity with age for most of the modules (please see figure 3 for the white-on-black high contrast mesopic module as a representative example).

Effects of Aging on Vision Measured in Myopic Eyes

The mean and standard deviation of the refractive error among the myopic eyes measured in each age group are presented in table 4; no significant refractive differences were found by ANOVA testing.

For the myopic eyes the comparison of the acuity results obtained with each of the six modules among the three age groups is presented in figure 4 for the spectacle correction and in figure 5 for the CL correction. The statistical comparisons for the acuity differences with age in the spectacle corrected eyes are shown in table 5 and for those corrected with CLs in table 6.

Figure 4: Mean and 95% confidence interval for the logMAR visual acuity measured with each CVA module among myopic eyes corrected with spectacles and divided into 3 age groups

Order of presentation	CVA module	Colour	Michelson contrast	Test simulates
1	CVA 98%M	1	98%	Mesopic - high contrast
2	CVA 25%M	2	25%	Mesopic - restaurant
3	CVA 50%M	3	50%	Mesopic – driving at dusk
4	CVA 10%P	4	10%	Photopic glare – sun over head
5	CVA 8%P	5	8%	Photopic glare – sun 15o off-axis
6	CVA 98%P	6	98%	Photopic glare – high contrast

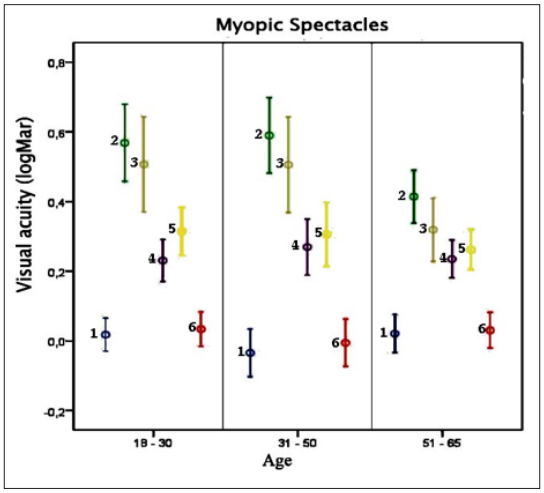

Figure 5: Mean and 95% confidence interval for the logMAR visual acuity measured with each CVA module among myopic eyes corrected with contact lenses and divided into 3 age groups

Order of presentation	CVA module	Colour	Michelson contrast	Test simulates
1	CVA 98%M	1	98%	Mesopic - high contrast
2	CVA 25%M	2	25%	Mesopic - restaurant
3	CVA 50%M	3	50%	Mesopic – driving at dusk
4	CVA 10%P	4	10%	Photopic glare – sun over head
5	CVA 8%P	5	8%	Photopic glare – sun 15o off-axis
6	CVA 98%P	6	98%	Photopic glare – high contrast

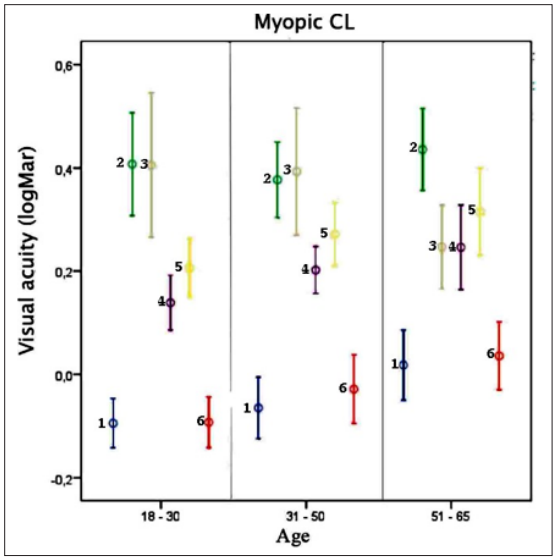

Table 6: Differences and post hoc Tukey test correlation of VA measured with each CVA module in the myopic eyes corrected with contact lenses among the three age groups. Differences that are significant (p<0.05) between the age groups are marked in yellow

CVA Module	(I) Age group	(J) Age group	Mean difference (I-J)	Standard error	p value Sig	95%-Confidence Interval VA (LogMAR)	
			LogMAR VA			Lower bound	Upper bound
CVA98%M	18 - 30	31 - 50	-0.02	0.04	0.48	-0.11	0.05
		51 - 65	-0.11*	0.04	0.01	-0.19	-0.03
	31 - 50	51 - 65	-0.08	0.04	0.05	-0.16	0.00
CVA 25%M	18 - 30	31 - 50	0.03	0.06	0.62	-0.09	0.15
		51 - 65	-0.02	0.05	0.63	-0.14	0.08
	31 - 50	51 - 65	-0.05	0.06	0.34	-0.18	0.06
CVA 50%M	18 - 30	31 - 50	0.01	0.08	0.88	-0.15	0.17
		51 - 65	0.15*	0.08	0.05	-0.00	0.31
	31 - 50	51 - 65	0.14	0.08	0.08	-0.02	0.31
CVA 10%P	18 - 30	31 - 50	-0.06	0.04	0.17	-0.15	0.02
		51 - 65	-0.10*	0.04	0.02	-0.19	-0.02
	31 - 50	51 - 65	-0.04	0.04	0.34	-0.13	0.04
CVA 8%P	18 - 30	31 - 50	-0.06	0.04	0.19	-0.16	0.03
		51 - 65	-0.10*	0.04	0.02	-0.20	-0.01
	31 - 50	51 - 65	-0.04	0.05	0.38	-0.14	0.05
CVA98%P	18 - 30	31 - 50	-0.06	0.04	0.13	-0.14	0.02
		51 - 65	-0.12*	0.04	0.01	-0.20	-0.04
	31 - 50	51 - 65	-0.06	0.04	0.14	-0.14	0.02
*. The mean difference is significant at the <0.05 level.							

In the myopic eyes corrected with spectacles, significant differences were found in both of the mesopic CVA 25% and CVA 50% modules when both the 18–30 age group and those aged 31-50 were compared with those aged 51-65, amounting to an improvement in visual acuity with aging in both modules ranging between 0.15 logMAR and 0.18 logMAR.

In the myopic eyes corrected with the contact lenses, a borderline significant worsening in vision was noted of 0.11 to 0.12 logMAR in both of the high contrast modules between the age group 18–30 and those aged 51–65. In the 10% and 8% the glare modules we observed a borderline significant decrease in acuity between the 18–30 age group and those 51–65. These differences, however, were considered borderline because they were similar to the test re-test 95% reliability confidence limits for each of the modules.

When the acuities for the myopic eyes were plotted against the age of the patients, all plots appeared to corroborate the conclusions demonstrated above (as a representative example please see figure 6 for myopic eyes corrected with spectacles measured with the high contrast mesopic, white-on-black module).

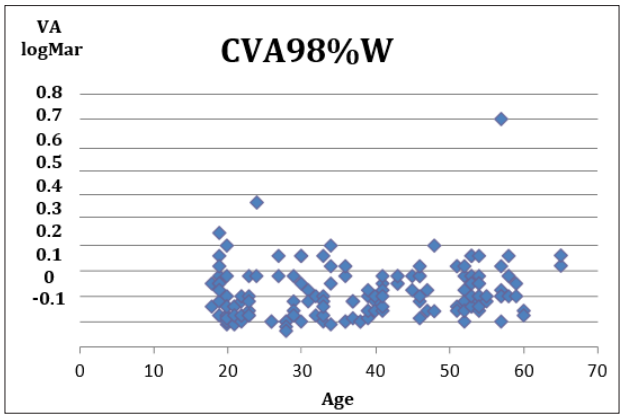

Figure 6: Comparison plot of visual acuity (Snellen 20/) measured with the CVA 98% white-on-black module versus age in the myopic eyes corrected with spectacles

Effects of Aging on Vision measured in Hyperopic Eyes

Among the hyperopic eyes, the mean and standard deviations of refractive error are presented in table 7; no significant differences were noted among the three age groups.

Table 7: Mean and Standard deviation of the refractive error among the different age groups for the hyperopic eyes

Age Group	SPH	CYL	Mean Age	Eyes (# Patients)
18-30	2.08 SD (±) 1.11	-0.26 SD (±) 0.33	22.61 SD (+/-) 4.07	62 (31)
31-50	1.71 SD (±) 0.76	-0.14 SD (±) 0.24	41.48 SD (+/-) 5.65	63 (32)
51-65	2.08 SD (±) 0.87	-0.19 SD (±) 0.3	56.38 SD (+/-) 4.37	43 (23)

The comparison of the vision results among the hyperopic eyes for each of the six modules is presented in figure 7 for the spectacles with statistical comparison presented in table 8 and for the contact lens eyes' the differences in acuity are presented in figure 8 with statistical comparisons presented in table 9.

Table 8: Differences of VA measured with each CVA module in the hyperopic eyes corrected with spectacles among the three age groups. Differences that are significant by the post hoc Tukey test (p<0.05) between the age groups are marked in yellow

CVA Module	(I) Age group	(J) Age group	Mean difference (I-J)	Standard error	p value Sig	95%-Confidence Interval VA (LogMAR)	
			LogMAR VA			Lower bound	Upper bound
CVA 98%M	18 - 30	31 - 50	0.03	0.03	0.27	-0.02	0.10
		51 - 65	0.01	0.03	0.86	-0.06	0.07
	31 - 50	51 - 65	-0.02	0.03	0.41	-0.10	0.04
CVA 25%M	18 - 30	31 - 50	-0.04	0.05	0.37	-0.14	0.05
		51 - 65	-0.04	0.05	0.45	-0.15	0.06
	31 - 50	51 - 65	0.00	0.05	0.95	-0.10	0.11
CVA 50%M	18 - 30	31 - 50	0.01	0.05	0.87	-0.09	0.11
		51 - 65	-0.04	0.05	0.45	-0.15	0.07
	31 - 50	51 - 65	-0.05	0.05	0.37	-0.16	0.06
CVA 10% P	18 - 30	31 - 50	0.01	0.04	0.73	-0.07	0.10
		51 - 65	-0.09	0.04	0.06	-0.18	0.01
	31 - 50	51 - 65	-.10*	0.04	0.03	-0.20	-0.01
CVA 8%P	18 - 30	31 - 50	0.03	0.04	0.40	-0.05	0.13
		51 - 65	-0.08	0.05	0.09	-0.18	0.01
	31 - 50	51 - 65	-.12*	0.05	0.01	-0.22	-0.02
CVA 98%P	18 - 30	31 - 50	0.01	0.03	0.84	-0.07	0.08
		51 - 65	-0.00	0.04	0.99	-0.08	0.08
	31 - 50	51 - 65	-0.01	0.04	0.85	-0.09	0.07
*. The mean difference is significant at p<0.05.							

Figure 8: Mean and 95% confidence interval for the logMAR visual acuity measured with each CVA module among hyperopic eyes corrected with contact lenses and divided into 3 age groups

Order of presentation	CVA module	Colour	Michelson contrast	Test simulates
1	CVA 98%M	1	98%	Mesopic - high contrast
2	CVA 25%M	2	25%	Mesopic - restaurant
3	CVA 50%M	3	50%	Mesopic – driving at dusk
4	CVA 10%P	4	10%	Photopic glare – sun over head
5	CVA 8%P	5	8%	Photopic glare – sun 15o off-axis
6	CVA 98%P	6	98%	Photopic glare – high contrast

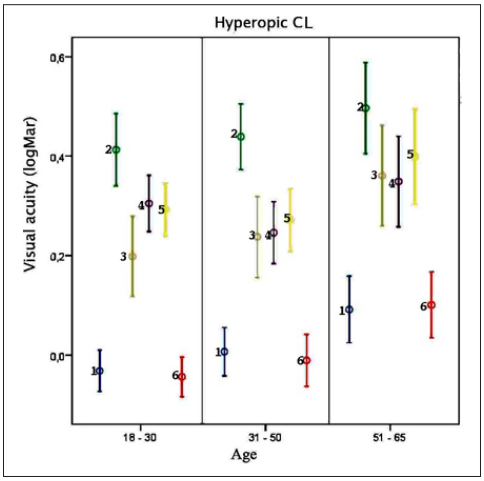

Table 9: Differences and post hoc Tukey test correlation of VA measured with each CVA module in the hyperopic eyes corrected with CL among the three age groups. Differences that are significant (p<0.05) between the age groups are marked in yellow

CVA Module	(I) Age group	(J) Age group	Mean difference (I-J)	Standard error	p value Sig	95%-Confidence Interval VA (LogMAR)	
			LogMAR VA			Lower bound	Upper bound
CVA98%M	18 - 30	31 - 50	-0.03	0.03	0.25	-0.10	0.02
		51 - 65	-.12*	0.03	<0.01	-0.19	-0.04
	31 - 50	51 - 65	-.08*	0.03	0.02	-0.15	-0.01
CVA 25%M	18 - 30	31 - 50	-0.02	0.05	0.60	-0.12	0.07
		51 - 65	-0.08	0.05	0.13	-0.19	0.02
	31 - 50	51 - 65	-0.05	0.05	0.30	-0.16	0.05
CVA 50%M	18 - 30	31 - 50	-0.03	0.05	0.50	-0.15	0.07
		51 - 65	-.16*	0.06	0.01	-0.28	-0.03
	31 - 50	51 - 65	-0.12	0.06	0.06	-0.24	0.00
CVA 10%P	18 - 30	31 - 50	0.05	0.04	0.19	-0.03	0.14
		51 - 65	-0.04	0.05	0.38	-0.14	0.05
	31 - 50	51 - 65	-.10*	0.04	0.04	-0.20	-0.00
CVA 8%P	18 - 30	31 - 50	0.02	0.04	0.63	-0.06	0.11
		51 - 65	-.10*	0.04	0.03	-0.20	-0.00
	31 - 50	51 - 65	-.12*	0.04	0.01	-0.22	-0.02
CVA 98%P	18 - 30	31 - 50	-0.03	0.03	0.33	-0.10	0.03
		51 - 65	-.14*	0.03	<0.01	-0.22	-0.06
	31 - 50	51 - 65	-.11*	0.03	<0.01	-0.18	-0.03
*. The mean difference is significant at p<0.05.							

With spectacle correction the hyperopic eyes demonstrated no statically significant decline in vision with aging among the mesopic modules. Among the photopic glare modules a borderline significant decline in vision was observed for 10% and 8% glare modules, of 0.1 logMAR and 0.12 logMAR respectively, when the age group 31–50 was compared with the 51–65 age group (p<0.003).

Measured with contact lenses, the hyperopic eyes demonstrated a significant decline in acuity in the mesopic 98% MC and 50% MC modules when the 18-30 age group was compared with the 51–65 age group (0.16 logMAR, p<0.001). When corrected with contact lenses, a small, but significant, decline in vision with aging was observed between the 18-30 and 51-65 age groups with all three of the glare modules, the differences ranging from 0.10 log MAR to 0.14 logMAR (p<0.001).

Among the photopic glare modules a borderline significant decline in vision was observed with spectacle correction only in the CVA 10% and 8% glare modules, of 0.1 logMAR and 0.12 logMAR respectively when the age group 31–50 was compared with the 51–65 age group (p<0.003, 5.26). When corrected with contact lenses, a small but significant decline in vision was again observed with aging between the 18-30 and 51-65 age groups with all three of the glare modules, the differences ranging from 0.10 logMAR to 0.14 logMAR (p<0.001). These differences, however, lie within the test-retest reliability 95% confidence limits of the CVA modules.

Discussion

Among prior studies that have been performed evaluating the effect of aging on acuity, all have evaluated high contrast visual acuity with charts, and all studies have used predominantly line scoring of the chart to record vision, both of which reduce sensitivity [22-23]. No changes were noted for age ranges in those studies equivalent to the ages evaluated herein when eyes were given optimal correction [1-3]. Similarly, studies evaluating contrast sensitivity that also were conducted in a lighted room with charts have

Demonstrated no change with aging among normal individuals [4]. However, in none of those prior studies was the influence of the type of correction investigated or controlled.

Age Changes in Mesopic Environments

In contrast to the prior studies, in this study differences were noted with aging in the mesopic modules among the emmetropic eyes demonstrating the greatest worsening in the 50% module (0.18 logMAR decline) but also borderline significant changes (but greater than the test-retest variability) in the 25% mesopic module (0.13 log MAR) and in the 98% MC mesopic module (0.12 logMAR). The decline was greater with the 50% mesopic module (driving at dusk) than that produced with the 25% module because, although it presented a higher contrast, the luminance was dimmer in the C presented as well as the background, the 25% module representing the observation of facial features while dining in a restaurant during evening hours. The measured decrease in vision is in line with the reported changes in lens optical density, retinal sensitivity, and tear film stability occurring within the age range that was studied [5-9,21,26].

The myopic group, if properly corrected for their refractive error, should have demonstrated the same aging behavior as the emmetropic eyes. However, with both spectacle and contact lens correction for the myopic eyes, we observed a significant improvement in vision with aging amounting to approximately 0.15 logMAR with both the 25% and 50% modules with spectacle correction as well as with CTL correction but only in the 50% module. The improvement was greater than the test-retest reliability for the CVA mesopic modules. We believe the myopic improvement in mesopic vision with aging can only be explained by the loss of accommodation that occurs with aging, which would remove the tonic over-accommodation that has been demonstrated among young individuals in such dim environments and, which has been documented to decline with age [24-26]. If this were the case, there may be less night aggravation of the induced myopia with high contrast letters, and indeed with the 98% contrast target in the mesopic module, no improvement was observed with aging (a worsening of 0.11 log MAR was noted with CL wear, but, it should be noted, is similar to the test-retest reliability). If this reasoning is correct, then the hyperopic group should not have demonstrated the same improvement with aging, since in this group tonic accommodation has been demonstrated not to cause the same refractive error aggravation [3]. Among the fully corrected hyperopic eyes, the mesopic modules produced no worsening with aging when corrected with spectacles. When corrected with contact lenses, a worsening with age was observed in the low luminance driving-at-dusk module that resembled the emmetropic eyes. Although a decrease in pupillary size has been documented with aging and may potentially explain the improvement in vision, it does not explain all of the observations among the different refractive groups [10].

It was of interest that within the myopic refractive group in the low light level of the 50% mesopic CVA (driving at dusk) Figure 5 & 6, both with spectacle and contact lens correction demonstrated an increase in VA and, in the older group, produced nearly the same acuity (logMAR 0.30 with spectacles, 0.25 logMAR with CL wear) The reason for this is unclear, but may be due to tear film changes among the older individuals that would negate the improved aberration control of the contact lenses. This may explain the reduction in contact lens wear preference under dim conditions that is often observed by clinicians as their patients age.

Age Changes in Photopic Glare Environments

In the myopic eyes among all three photopic modules, 98%, 10%, and 8 %MC, there was a small 0.10 to 0.12 log MAR decrease in acuity for CTL wearers with aging, while with spectacles visual acuity remained approximately stable, with both corrections producing a similar acuity in the oldest age group.

In the hyperopic eyes corrected with contact lenses, a statistically significant decrease in acuity was observed with aging among all of the CVA glare modules. However, this was considered clinically insignificant as it was similar to the test-retest reliability of the CVA testing, while that with spectacles remained fairly constant. Similar to the myopic eyes, in the oldest age group the acuity was the same when corrected with either CLs or spectacles.

Although the differences noted with aging were small and similar to the test-retest reliability of the CVA modules, they may, perhaps, be explained by the aggravated veiling glare in the eyes of older individuals that is induced by the bright background effectively washing out the contrast of the presented Landolt C [28-30].

Conclusion

When the effect of aging on fixation acuity, measured with the CVA, was evaluated in emmetropic eyes, a significant decline was found, that was greatest in the 50% mesopic module (0.18 logMAR decline), but also demonstrated borderline significant changes (but greater than the test-retest variability) in the 25% mesopic module (0.13 logMAR) and in the 98% MC mesopic module (0.12 logMAR). The decline was greater with the 50% mesopic module than that produced with the 25% module because, although it presented a higher contrast, the luminance was dimmer in the C presented as well as the background (each representing necessarily visualized targets in their respective environments).

The measured decrease in acuity is in line with the reported worsening in lens optical density, retinal sensitivity, and tear film stability that occur with aging [5-9,17]. In contrast to the emmetropic eyes, a significant improvement in acuity in the mesopic modules was observed with aging among the myopic eyes, approximately 0.15 logMAR (greater than the test-retest reliability). We believe the improvement with aging in myopic eyes can only be explained by the loss of accommodation that occurs with aging and would remove the tonic over-accommodation that has been demonstrated among young individuals in such dim environments [24,25]. If this reasoning was correct, then the hyperopic group should not have demonstrated the same improvement with aging, and indeed, among the fully corrected hyperopic eyes, the mesopic modules produced a worsening with age that resembled that of the emmetropic eyes.

In both the myopic and hyperopic eyes among all three photopic glare modules but primarily with the low contrast, 10%, and 8 % MC, there was a small 0.10 to 0.12 logMAR worsening of acuity

observed with aging when corrected with contact lenses while with spectacles, visual acuity remained approximately stable, with both corrections producing a similar acuity in the oldest age group. No significant changes were noted with aging in the emmetropic group among these modules.

Conflicts of Interest

W Gutstein: None

SH Sinclair: Sinclair Technologies, LLC

P Presti: Sinclair Technologies, LLC

RV North: None

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