COMPARISON of STANDARD PRINT IMAGE TESTING and A GAUSSIAN IMAGE DIAGNOSTIC SYSTEM for VDT USERS

An Alternative Data Analysis Method

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Abstract

A previously published study compared the results of two nearpoint test targets used for prescribing eyewear for computer users. A standard print image and a device using images similar to those generated on a computer screen ("Gaussian images") were incorporated into tests of lag of accommodation. Correlational analysis was used to reach the conclusion that the Gaussian image device was better than the standard print image in simulating the environment of VDT users. This paper provides an alternative method of data analysis that may be more appropriate for this type of a study. Mean differences and 95% limits of agreement are described and used to reanalyze the data from the previous study. These techniques avoid some of the problems of correlational analysis that may adversely affect the interpretation of results.

Key Words

video display, computer users, Gaussian image, accommodation, PRIO®

A unique accommodative target used for nearpoint testing, the PRIO® VDT Prescription System, is commercially available and is intended to address the problems and symptoms experienced by computer users.[1-3] The PRIO® device uses Gaussian image-based characters, much like those generated on a computer screen. Computer pixels, the very small units which form letters and other characters on a VDT (video display terminal) screen, are not uniform and distinct, but, in fact, have luminance levels that change across each pixel. This luminance change is much like that of a bell-shaped, or "Gaussian," plot, where the luminance level gradually increases from the edge of the pixel, reaches a maximum in the center of the pixel, then gradually drops off again. The resulting images produced by these pixels are, therefore, slightly degraded and less distinct when compared to standard printed characters. Microplot analysis of the PRIO® device shows that the light output of the pixel images do seem to match those produced by an IBM PC computer.[4] These microplots, in fact, aren't quite a true Gaussian ("bell-shaped") stimulus, but they are very different from a high contrast "square-wave" image, like that found on standard black on white print nearpoint targets.

As image quality declines, it is believed that the accommodative response decreases, resulting in an increased "lag" of accommodation. Ultimately, in the absence of an accommodative stimulus (e.g., in darkness or in an empty visual field), accommodation reaches a point known as the "dark focus," or the resting point of accommodation (RPA).[5,6] It is hypothesized that computer users cannot focus accurately on the degraded VDT images because the accommodative response to these Gaussian images is much different than one would predict based solely upon testing distance, with the response actually approaching the RPA. The resulting accommodative instability may be a cause of fatigue and eyestrain among computer users. Thus, optometric nearpoint testing using the PRIO® system may lead to near lens prescriptions that may more effectively reduce near symptoms than prescriptions resulting from testing using standard printed nearpoint targets.

Despite the innovative design, the potential diagnostic and therapeutic applications of such a device, few studies of the effectiveness of the PRIO® system have been reported in the optometric literature. Recently, Salibello[4] reported the results of lag of accommodation testing by dynamic retinoscopy on 18 computer users, using two different near targets. The first target was a standard print MEM retinoscopy test card, the second was the PRIO® VDT System device, each placed at 50 cm. Low-neutral nearpoint retinoscopy was performed using each of these targets, and the results were compared to a fogging procedure which measured what Salibello

Table 1.
Distance Refractive Errors and Nearpoint Accommodative Levels (values are in diopters and represent spherical equivalents)

Subject	Refractive Error	Print	Gaussian	CVrpa
1	-3.00	-2.00	-1.13	-0.25
2	0.50	1.13	2.13	2.50
3	-2.25	-1.25	-0.63	-1.38
4	2.25	3.25	4.88	4.25
5	-3.50	-2.88	-2.00	-1.25
6	-4.00	-3.38	-2.50	-1.88
7	0.25	0.38	2.00	2.38
8	-1.75	-1.50	-0.38	0.00
9	-0.25	-0.25	0.88	1.75
10	0.00	0.25	1.75	2.25
11	-0.75	-0.50	0.50	1.50
12	0.50	0.75	1.63	2.63
13	2.25	0.63	1.75	2.25
14	0.50	0.75	2.25	2.13
15	-0.75	-0.38	0.50	1.25
16	0.13	0.75	1.25	2.38
17	-0.75	-0.50	0.88	1.63
18	-0.25	0.25	1.13	2.00

called the Clinical Value Resting Point of Accommodation (CVrpa). Simple correlational analysis was used to interpret the results, and Salibello concluded that the Gaussian image system "successfully serves as a clinical simulator for a typical video display terminal."

Salibello was comparing the results of different tests of accommodative response, in effect judging the level of agreement between the CVrpa and the two methods of accommodative lag testing. His conclusion was based on the stronger correlation between CVrpa and the Gaussian image target result (i.e., the higher correlation coefficient, r). Unfortunately, analysis, using correlations, can be misleading when one is attempting to determine similarity between two tests. In fact, it is quite likely that two tests that are designed to measure the same quantity will have a very high correlation despite poor agreement. Correlation is simply a measure of a linear relationship, not of similarity of results. Bland and Altman[7] and Zadnik, et al[8] described an alternative statistical technique which results in a more appropriate indication of agreement.

The technique described by Bland and Altman involves calculating the average (mean) difference between two measurements on a sample of subjects, and using the standard deviation of these differences as an indicator of agreement. Ideally, if two tests agree well, the average difference of the results should be close to zero. And the range which includes 95% of the sample (or the mean +/-1.96 times the standard deviation) should be small. This range is called the 95% "limits of agreement." The results can also be displayed graphically for a visual representation of agreement. This paper will reanalyze the data from Salibello's original study, using this mean difference technique, and will display graphically the 95% limits of agreement.

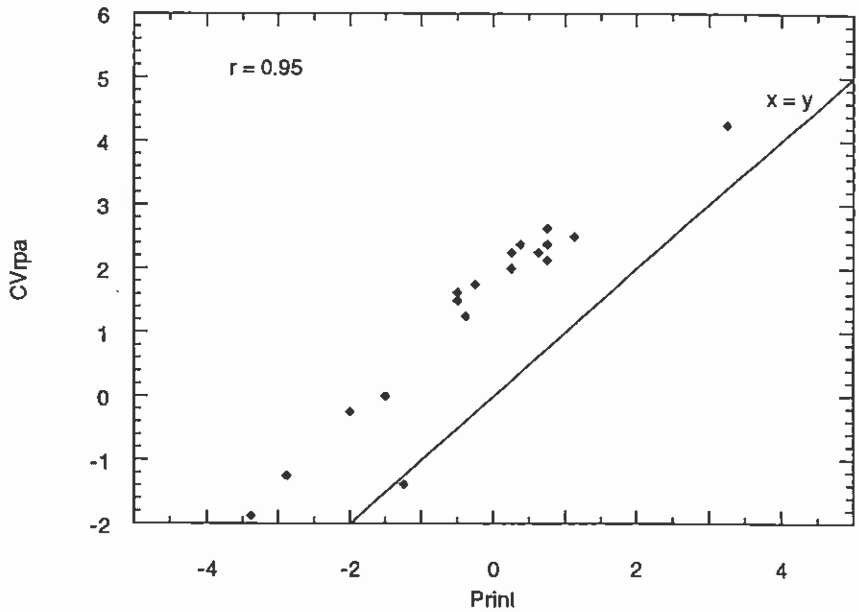

Figure 1. Scatterplot of standard print image findings vs. clinical value of the resting point of accommodation.

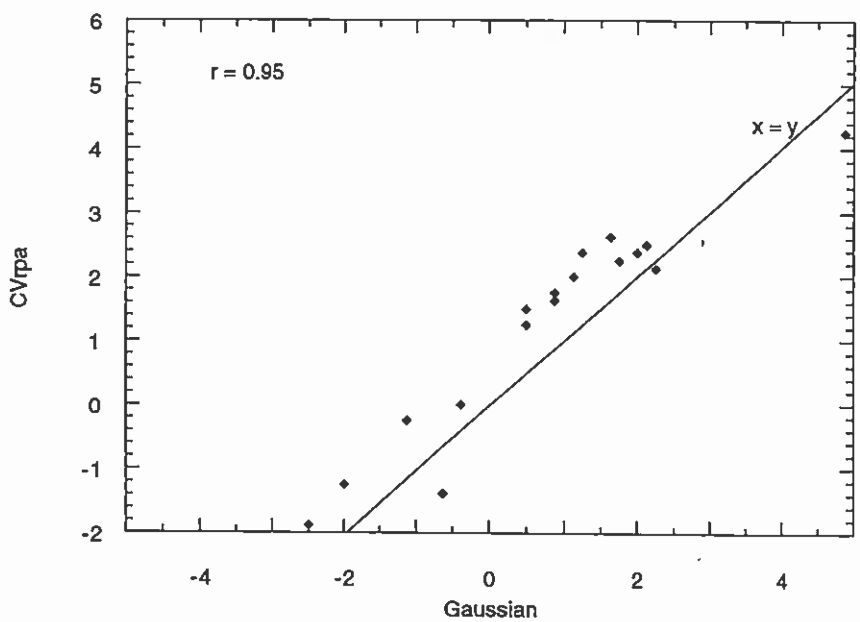

Figure 2. Scatterplot of Gaussian image findings vs. clinical value of the resting point of accommodation.

METHODS

Salibello[4] described in detail the dynamic retinoscopy techniques he used to assess lag of accommodation with two different targets. Basically, low-neutral nearpoint retinoscopy was performed, us-

Subject	Mean CVrpa-Print	Difference CVrpa-Print	Mean CVrpa-Gaussian	Difference CVrpa-Gaussian
1	-1.13	1.75	-0.69	0.88
2	1.81	1.38	2.31	0.38
3	-1.31	-0.13	-1.00	-0.75
4	3.75	1.00	4.56	-0.63
5	-2.06	1.63	-1.63	0.75
6	-2.63	1.50	-2.19	0.63
7	1.38	2.00	2.19	0.38
8	-0.75	1.50	-0.19	0.38
9	0.75	2.00	1.31	0.88
10	1.25	2.00	2.00	0.50
11	0.50	2.00	1.00	1.00
12	1.69	1.88	2.13	1.00
13	1.44	1.63	2.00	0.50
14	1.44	1.38	2.19	-0.13
15	0.44	1.63	0.88	0.75
16	1.56	1.63	1.81	1.13
17	0.56	2.13	1.25	0.75
18	1.13	1.75	1.56	0.88
Mean		1.59		0.51
SD		0.51		0.53
1.96 * SD		1.01		1.04
95% limits of agreement	0.58 to 2.60		-0.53 to 1.55	

Table 2. Means and differences used for analysis (Values are in diopters)

ing a standard print MEM card and the Gaussian image PRIO® VDT System. In addition, a CVrpa was determined and compared to the lag of accommodation findings. Table 1 lists the nearpoint accommodative lag results reported by Salibello for 18 different subjects. The reported conclusions were based on how similar each of the lag of accommodation results were to the CVrpa testing.

Figures 1 and 2 are scatterplots of these data, similar to those given in the original paper. The line of equality (x = y) has been drawn for comparison purposes. Both plots show a very high correlation, r = 0.95 for each; thus, there does appear to be a strong linear relationship between each of the two lags of accommodation and the CVrpa. Although it does seem that the data points for the PRIO® system lie closer to the line of equality than the data points for the standard print target, no definitive conclusions regarding agreement can be drawn from the scatterplots or from the correlations.

Using the techniques described by Bland and Altman,[7] the reported data were reanalyzed. First, the differences between each of the lag of accommodation tests and the CVrpa for each subject were determined, as well as the mean difference and standard deviation for all subjects. Statistically, 95% of the subjects can be found in a range from 1.96 times the standard deviation above to 1.96 times the standard deviation below the mean. For this reanalysis, the mean differences and the 95% limits of agreement were calculated for each accommodative target and the results were plotted.

RESULTS

The differences, means, standard deviations, and 95% limits of agreement are shown in Table 2. In order to graphically display these data, the difference between results is plotted against the best estimate of the actual accommodative lag for each subject. The best estimate of the actual lag is the mean of the retinoscopy lag of accommodation result and the CVrpa. These mean results are also given in Table 2.

Figures 3 and 4 graphically show the results of the "mean difference analysis" and the 95% limits of agreement. It can be seen, first of all, that the mean difference between the Gaussian image target lag of accommodation and the CVrpa (0.51 D) is much closer to zero than the mean difference between the standard print target lag of accommodation and the CVrpa (1.59 D). The mean +/-1.96 standard deviations is the shaded portion of each plot and represents the 95% limits of agreement (-0.53 D to +1.55 D for the Gaussian image target and +0.58 to +2.60 D for the print target). Although the 95% limits of agreement are very similar in terms of the size of the range, this range for the Gaussian-image target includes zero.

DISCUSSION

By comparing lag of accommodation measurements using nearpoint retinoscopy to the CVrpa, Salibello was attempting to determine the similarity between each of the retinoscopy tests of accommodative lag and the CVrpa test. Correlations between the two sets of data were both very high, so it is difficult to say whether one retinoscopy method or the other agreed more with CVrpa testing, or even to what degree each agreed with CVrpa. The high correlations were only an indication of the strong linear relationship between the variables, which one might expect since all tests are evaluating lag of accommodation status.

Mean difference analysis and the determination of the 95% limits of agreement show that lag of accommodation

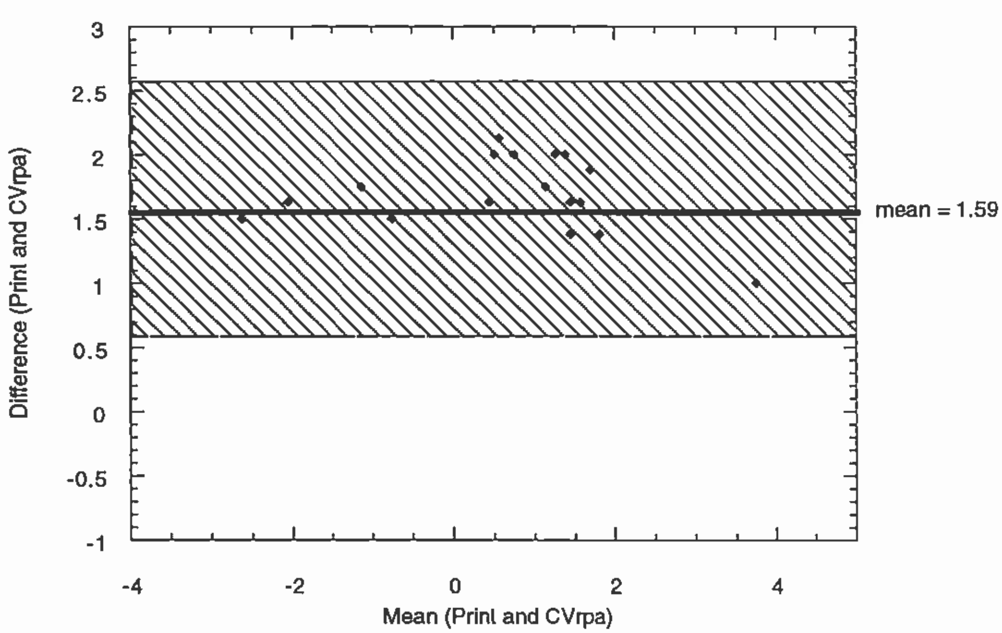

Figure 3. Mean difference analysis of standard print images and clinical value of resting point of accommodation.

testing using the Gaussian image target matched CVrpa results much more closely than standard print targets. Thus, it may be that the images generated by the indistinct pixels of a computer monitor cause an inadequate accommodative response, which could, in turn, be partially responsible for the eyestrain and fatigue symptoms experienced by many computer users. The optometrist may be better able to assess and manage these problems using the Gaussian image testing system, based upon the results of this study.

Two additional comments about the original study unrelated to the methods of data analysis can be made. First of all, the examiner was aware of which near target was being used. Thus, potential examiner bias may have influenced the low-neutral retinoscopy results. This design problem could be addressed by repeating the study and simply masking the examiner during nearpoint testing or, perhaps, by using multiple examiners. Secondly, although lag of accommodation testing using a Gaussian image may result in a higher lag of accommodation, it is not clear how this result would be used to determine a near prescription, or how effective this prescription would be in relieving the symptoms of computer users.

CONCLUSION

Mean difference analysis of data from a previously published study indicates that lag of accommodation testing using a Gaussian image-based target (the PRIO® VDT System) agrees with a clinical test of the resting point of accommodation more than lag of accommodation testing using a standard print target. This type of testing may be helpful in managing the symptoms of computer users. However, an examiner-masked study would reduce potential bias in measuring lag of accommodation. Mean difference analysis could be used to determine the differences between tests of accommodative lag and tests of resting point of accommodation using different near targets. Additionally, it is unclear how clinically significant these differences might be. It would be helpful for a study to evaluate the symptomatic relief and improvement in comfort of prescriptions determined using testing techniques involving standard test targets and the PRIO® VDT System. Planning for such a study is currently underway.

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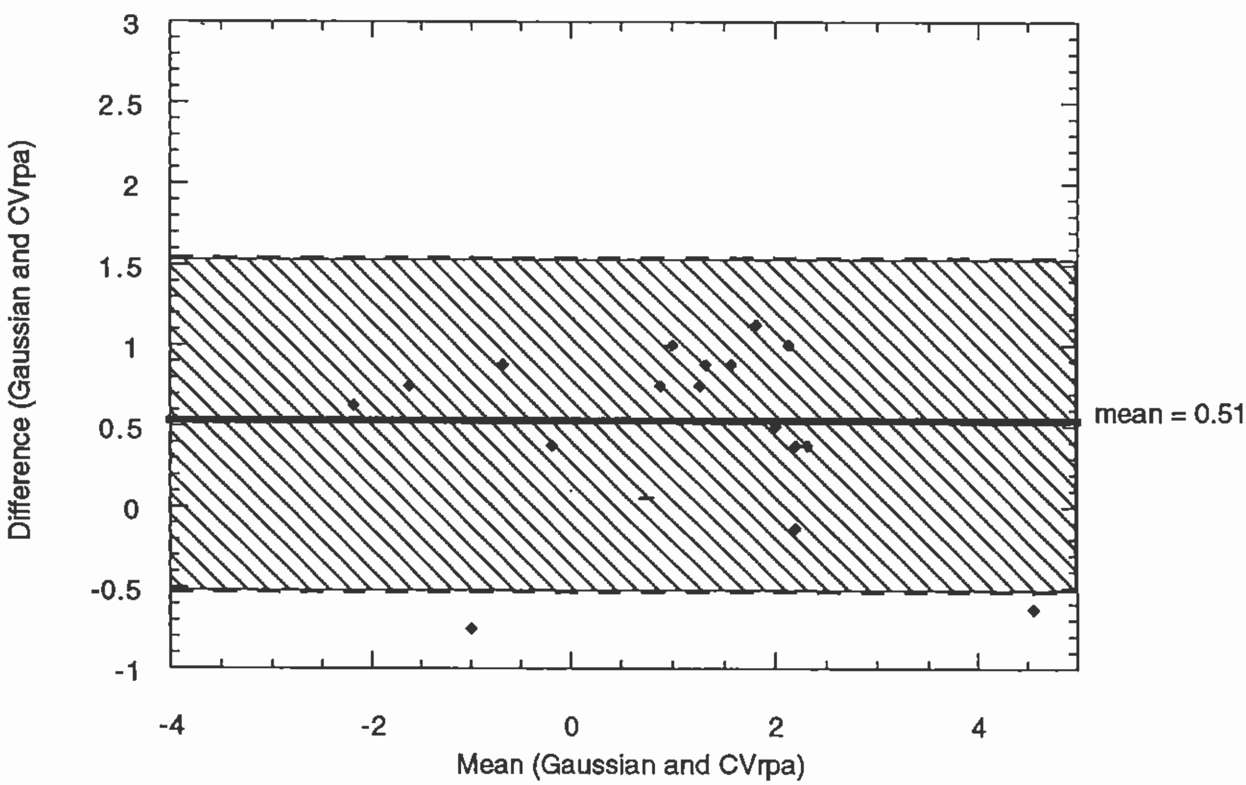

Figure 4. Mean difference analysis of Gaussian images and clinical value of resting point of accommodation.