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Abstract

Introduction: Contrast sensitivity is a visual element used in optometric examinations to help assess visual capacity. This study compared two formats of contrast sensitivity tests, ETDRS Letters and Continuous Text.

Methods: Contrast sensitivity was measured in 75 subjects, who met inclusion criteria, using the Adult Near Contrast Test. Patients' verbal readings provided data for the formats at five contrast levels. Results: Average visual acuity and number of lines/paragraphs read correctly decreased with decreasing contrast. ANOVAs showed significant differences by contrast level in total words and total letters ($p < 0.001$) and a Pearson correlation gave high correlations between the contrast sensitivity readings of the two formats except at 100% contrast ($p < 0.05$; $p = 0.69$).

Conclusion: Analysis revealed that contrast sensitivity readings from the different formats were essentially the same for most contrast levels. These two test formats can both be used with success in measuring contrast sensitivity in a normally sighted population.

Keywords

contrast sensitivity, reading



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Contrast Sensitivity Testing in Visually Normal Individuals: Letter vs. Continuous Text

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Implications for Interprofessional Practice

1. Good contrast detection is of vital importance in activities of daily living.
2. There is little consensus on the proper format for contrast sensitivity testing.
3. This study shows that both chart formats are acceptable for measuring contrast sensitivity.

Introduction

Contrast sensitivity (CS) is a description of the visual system's ability to discriminate targets having small differences in luminance across space (Thayaparan, Crossland, & Rubin, 2007). Detecting contrast is an essential feature of vision that can provide information about a patient's visual function that is independent of visual acuity (Haymes et al, 2006). Consequently, CS acts as a valuable supplement to traditional visual acuity assessments in both clinical settings and in human engineering applications (Scialfa, Adams, & Giovanetto, 1991). Tools for measuring CS include the Pelli-Robson chart, the Mars letter contrast sensitivity chart, and the Test Chart 2000 (Thayaparan et al., 2007). These tests typically have been used to assess CS in patients whose vision cannot be corrected to at least 20/20 on a high contrast Snellen chart (Thayaparan et al., 2007). However, the additional information concerning visual function provided by CS testing has resulted in the recognition of CS tests as valid visual tools that should be used in the optometric examination of patients with normal vision (Scialfa et al., 1991). This expansion of CS testing to normal vision patients aims at improving overall patient care by examining an additional visual function.

The incentive for using CS testing in normal vision patients is that contrast detection affects everyday living and bodily health (Haymes et al, 2006). Previous research has shown that good contrast detection facilitates numerous common activities such as driving, reading, walking, performing computer tasks, and recognizing faces (Haymes et al, 2006). A reduction in CS has been shown to inhibit the ability to perform these activities and similar everyday tasks, thereby decreasing overall quality of life (dos Santos & Andrade, 2012).

Furthermore, CS has been used as a tool for diagnosing and monitoring diseases such as glaucoma, cataracts, and optic neuritis (Haymes et al., 2006). For example, CS testing has been used to assess the condition and monitor the progress of stroke patients (dos Santos & Andrade, 2012). Stroke can result in numerous visual impairments, some of which can be

explained by a reduction in CS (dos Santos & Andrade, 2012). Quantification of CS loss can be used as a benchmark for documenting the adverse effects of stroke and for monitoring the progress achieved with therapy (dos Santos & Andrade, 2012). Additionally, CS has been used to evaluate patients with retinitis pigmentosa (RP), a disease characterized by night blindness and decreased extent and sensitivity of the peripheral visual field (Oishi et al., 2012). This loss of peripheral visual function makes the functionality of the RP patients' central vision that much more important, (Oishi et al., 2012). Notably, contrast visual acuity (CVA), another technique used for measuring CS, has been reported as decreased in patients with RP prior to detection of substantial or even measurable decreases in high contrast visual acuity. Therefore, testing CS could result in detection of minor changes in central visual function that could help to more accurately assess the vision and pathological changes present in RP patients, providing the patient with earlier and better vision care and improved quality of life (Oishi et al., 2012).

The Pelli-Robson chart, the Mars contrast sensitivity chart, and the Test Chart 2000 are three clinical charts commonly used to determine CS (Thayaparan et al., 2007). The reliability of these charts, as well as their effectiveness and ease of incorporation into regular eye examinations has been investigated (Haymes et al., 2006; Thayaparan et al., 2007). These three charts, however, are either letter display or pattern grating charts; none use continuous text, such as paragraphs, to analyze CS (Thayaparan et al., 2007). Paragraphs provide more natural reading stimuli and may give a better understanding of the patient's visual function. Whether on the computer, cell phone, or traditional print media, patients with decreased vision are impacted negatively. Understanding the impact of poor CS on complete text sentences may shed light on how best to aid visual function.

The present investigation compared CS measured with letter stimuli to contrast sensitivity measured with paragraph stimuli. The Adult Near Contrast Test (Richmond Products) contains both types of stimuli: an EDTRS letters format and a continuous text for-

mat. We hypothesized that a higher CS score would result with the continuous text format rather than with the letter format, since paragraph format is more familiar to most subjects and since the context of the story could aid the identification of low contrast text.

Methods

Participants

Participants consisted of 75 adults between the ages of 22-35 years. Inclusion criteria consisted of best-corrected vision of 20/32 or better in each eye separately and together at near and stereocuity equal to or better than 30 seconds of arc (Randot Wirt Circles, Stereo Optical Co., Inc, 1995). The study was approved by the Institutional Review Board at the Southern College of Optometry, and informed consent was obtained from each subject before participation.

Apparatus/Materials

The study was conducted using the Adult Near Contrast Test (Richmond Products). This test consists of both EDTRS format letter charts and continuous text charts at five different contrast levels: 100%, 25%, 10%, 5%, and 2.5% (Figure 1). Each chart is comprised of individual letters or paragraphs of words that decrease in size from top to bottom, thereby assessing one contrast level for different target sizes on a single chart. Letter size remains constant for a given line on the EDTRS chart, and letter size varies from 20/400 (top line) to 20/10 (bottom line). The target sizes of the continuous text format range from 20/100 (top paragraph) to 20/20 (bottom paragraph), with 7 short paragraphs present on each chart. Print size does not change within a given paragraph. The test distance was 40 cm, and full room lighting with an additional overhead lamp was used to maintain an approximate luminance of 85 +/- 25cd/m². Copies of the two chart formats at the five contrast levels were printed for the investigator to use for scoring incorrect responses while the subject read the test chart.

Procedure

The Adult Near Contrast Test chart was held by the subject 40 cm from his/her eyes while he/she was seated. Distance correction was used throughout testing. The overhead lamp was adjusted to adequately illuminate the chart. For each contrast level, the subject, viewing binocularly, read the EDTRS letters from highest contrast to lowest contrast and then the continuous text, again from highest to lowest

contrast. During these reading periods, subjects were encouraged to take their time and were informed that they could tilt the test as needed to ensure that glare would not contribute to an inability to read the charts. Test order was randomized.

To score the performance on the EDTRS letters charts, the number of errors per row was recorded by the investigator on the printed testing templates. For the 100% contrast chart, testing was terminated after the subject made 3 errors on a single row of letters. Testing continued with the remaining contrast levels, highest to lowest, with testing terminated at each contrast level when 3 errors were made on a single row of letters. After all five contrast levels were completed, the corresponding visual acuity levels (smallest lines read) and the number of total correct letters per contrast level were recorded. If the subject was able to read one or two letters on the line below the previous line on which he or she missed 3 letters, those letters were included in the total letters portion of the data. All scoring was performed in accordance with the provided testing manual.

For the continuous text targets, subjects read each paragraph of the 100% contrast chart; testing terminated when more than half of the words in a paragraph of a given text size were incorrectly read. Testing proceeded with the subject reading the subsequent pages of continuous text, in order of decreasing contrast (Figure 2). Testing was terminated for each contrast level when more than half the words in a paragraph of a given text size were incorrectly read. For each contrast level, the smallest text size and the total number of words correctly read were recorded. All scoring was performed in accordance with the provided testing manual.

Data Analysis

The visual acuity (smallest targets accurately read) for each contrast level was recorded for each subject for both the EDTRS letters and continuous text charts. The total number of correct letters or words read by the subject for each contrast level was also recorded. For both formats of the test, the mean number of lines read per contrast level and average visual acuity per contrast level were calculated. Pearson correlations between letters and words for each contrast level were performed, and repeated measures ANOVAs were used to test for differences by contrast level for each of the formats. Significance levels for all analyses were set at 95 percent ($p \leq 0.05$) (Stata SE software).

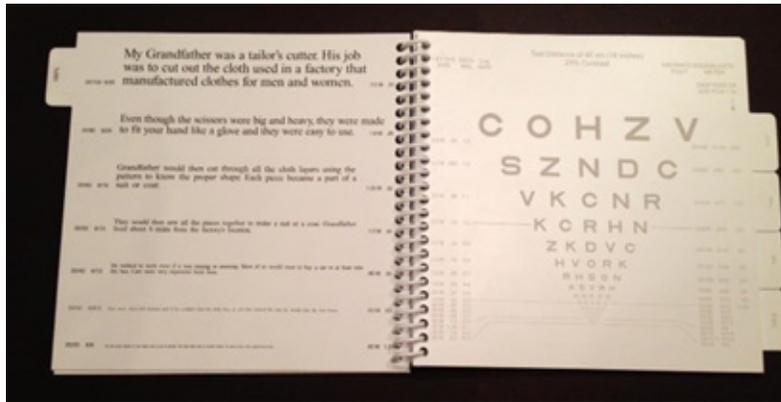


Figure 1: Illustration of the Adult Near Contrast Test

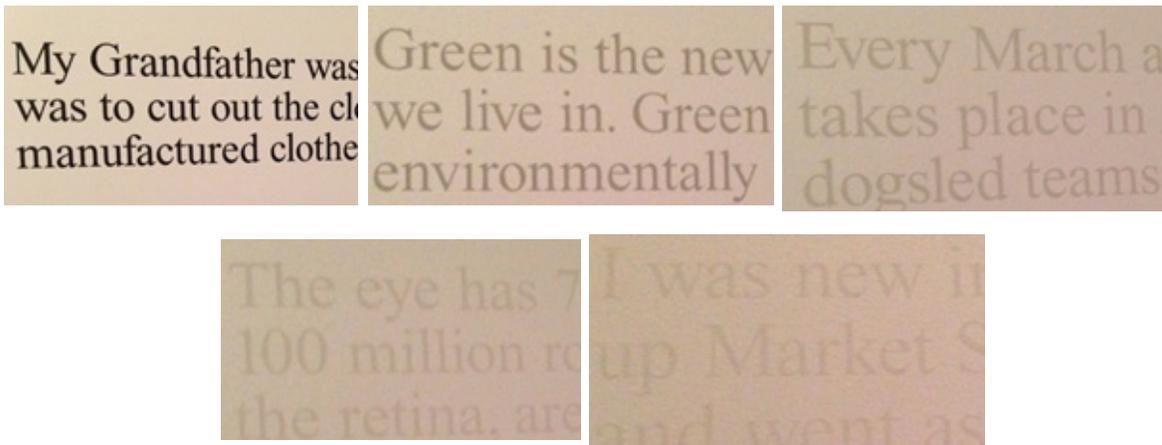


Figure 2: Continuous Text Format of the Adult Near Contrast Test. The five images represent the five contrast levels of the test: 100%, 25%, 10%, 5%, and 2.5% (Left to right, Top to bottom)

Contract Level	Avg VA-EDTRS Chart	Avg VA-Continuous Text Chart
100%	20/15.5	20/20
25%	20/21.2	20/26.7
10%	20/27.1	20/27.8
5%	20/31.7	20/30.4
2.5%	20/36.9	20/35

Table 1: Average visual acuity for the EDTRS and Continuous text formats.

Results

For the EDTRS letters format, the mean visual acuity was highest at the 100% contrast level (20/15.5) and lowest at the 2.5% contrast level (20/36.9). Similarly, the mean visual acuity for the continuous text format was highest at the 100% contrast level (20/20) and lowest at the 2.5% contrast level (20/35). Table 1 illustrates the reduction in visual acuity that occurred with decreased contrast in both formats.

Furthermore, the average number of lines or paragraphs correctly read by the subject was recorded per contrast level. Table 2 shows the results for the EDTRS letters and Continuous Text formats. Out of 17 lines, the highest mean number of lines read correctly was 15.2 at 100% contrast. The mean number of lines correctly read decreased sequentially with decreasing contrast, with 11.6 lines correctly read at

the lowest contrast level (2.5%). At 100% contrast, the mean number of paragraphs correctly read on the Continuous Text format equaled the total number of paragraphs on the chart. The mean number of paragraphs correctly read decreased with decreasing contrast, with a minimum mean of 5.72 paragraphs correctly read at the 2.5% contrast level.

Repeated measures ANOVAs were conducted to examine the effects of contrast level on (a) total letters (EDTRS letters format) and (b) total words (continuous text format). Significant differences based on contrast level were found for total letters ($p < 0.001$) and for total words ($p < 0.001$). A Pearson correlation was performed between total letters and total words for each contrast level. The results are displayed in Table 3. High and statistically significant correlations between words and letters occurred at all contrast levels ($p < 0.001$), except for the 100% contrast targets ($p = 0.69$).

Contract Level	Average Number of Lines	Average Number of Paragraphs Read
100%	15.2	7
25%	13.8	6.44
10%	12.7	6.35
5%	12.1	6.11
2.5%	11.6	5.72

Table 2: Average Number of lines read correctly for the EDTRS and Continuous Text formats.

Contrast Level	Pearson Correlation coefficient	Significance
100	0.05	$p = .69$
25	0.74	$p < 0.0001$
10	0.66	$p < 0.0001$
5	0.68	$p < 0.0001$
2.5	0.71	$p < 0.0001$

Table 3: Pearson correlation coefficients based on contrast level

Discussion

This study found a clear relationship between visual acuity and contrast level. In both the EDTRS letters format and the continuous text format, the mean visual acuity decreased with lower contrast. Similarly, the mean number of lines or paragraphs correctly read in the EDTRS letters format and the continuous text format decreased with decreasing contrast. These patterns indicate that as contrast decreased, subjects experienced more difficulty discriminating the objects

displayed on the page.

A comparison of the mean visual acuity recorded for each format did not show that the continuous text format resulted in significantly higher measures of CS. On the contrary, mean visual acuity was actually greater for the EDTRS letters format at three of the five contrast levels tested; the continuous text format only resulted in greater CS at the lowest two contrast levels. These results could have occurred because of the difference in minimum target size between the

two tests: the EDTRS letters format can measure visual acuities of 20/10, whereas the continuous text format can only measure a visual acuity as low as 20/20. Therefore, at the higher contrast levels, for which subjects can easily discriminate the objects on the charts, a better visual acuity was possible to record with the letters than with the continuous text because smaller visual acuity targets were displayed on the letters chart. Since these smaller visual acuity targets were not on the continuous text format charts, whether or not the subjects would have been able to read the corresponding paragraphs is unknown.

Overall, the mean visual acuity data did not indicate a clear difference in measured contrast sensitivity between chart formats. With respect to the mean number of lines or paragraphs correctly read, a slight difference between the EDTRS letters and the continuous text formats was measured across contrast levels, with the text resulting in more page content being correctly read; however, this difference was not statistically significant. Two separate ANOVAs, with letters and words as the dependent variables, tested differences by contrast level for each of the formats. These ANOVAs showed significant differences in performance between contrast levels for both total letters correctly read ($p < .001$) and total words correctly read ($p < .001$). A Pearson correlation between total letters and total words for each contrast level yielded correlations and p values that indicate a significant positive correlation between the two test formats, except at the 100% contrast level. These large positive correlations indicate that there was not a significant difference between the CS results of the two formats; therefore the test formats generated essentially equal CS measurements. This correlation applies to the two formats at the 25%, 10%, 5%, and 2.5% contrast levels, but not at the 100% contrast level. At 100% contrast, a correlation between the two test formats was not evidenced, possibly due to a lack of variation in the total word and letter scores for the 100% contrast level: 93% of the sample had a total of 180 or 181 words or letters correctly read out of 181 targets present. We are unable to explain why the average number of lines read on the Continuous Text format at 100% was not 17, the highest number possible. The lack of significance at 100% contrast would not have been impacted though.

For efficiency of data collection in the clinic setting, instruments used to measure visual function generally present a limited selection of target parameters that vary in a regular, step-wise manner. Lack of consistency in the variation of some of these pa-

rameters across instruments designed to assess the same function can make comparisons of performance between instruments complicated. In this study, for example, a clearer picture of whether single letter or continuous text format permits a more sensitive measure of contrast would likely emerge if the two chart formats contained targets with identical visual acuity levels. Additionally, to test whether word recognition in context contributes to higher measured CS values, a contrast test using continuous text without a story-line should be developed. Testing contrast sensitivity with continuous text using text with and without context would enable researchers to determine if any difference in measured contrast sensitivity is primarily due to guessing or to an actual ability of the continuous text format to yield greater contrast sensitivity.

Conclusion

This study demonstrates a positive correlation between the two testing formats contained in the Adult Near Contrast Test for measuring CS in adults with normal vision. Comparison to other near CS tests should be made to confirm test validity in both the normal and low vision populations.

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