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The effect of room illumination on distance visual acuity using a projected chart

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The effect of room illumination on distance visual acuity using a projected chart

Abstract
Historically distance visual acuity (DVA) has been measured in darkened conditions and the assumption has been that different exam room illuminations do not affect DVA in individuals. Recently, there has been some evidence that a particularly dark exam room may degrade acuity in some individuals. This DVA degradation in healthy individuals could be due to night myopia effects or increased optical aberrations. However, a bright exam room may cause reduced chart contrast resulting in lowered DVA as well. The purpose of this study was to determine whether changes in general room illumination can have a significant affect upon DVA. In this study, the DVA's of 37 healthy subjects between the ages of 12 and 49 were measured at three statistically different room illumination levels (300-440 lux, 100-200 lux, and 1-50 lux, p=0.0001) with a projected Flom (or S-) chart. The three subject groups mean DVA's for the three room illumination levels were compared using ANOVA repeated measures test. No significant differences were found between the three mean DV A's (LogMAR -0.078, -0.097, and -0.100 at bright, medium, and dim lighting levels respectively, p=0.234). This suggests that DVA was not affected by changes in general room illumination. However, there was a small subgroup of subjects whose DVA was significantly reduced at the lower room illuminations. The possibility that these subjects represent a clinically significant subgroup of patients who are night myopes is explored.

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THE EFFECT OF ROOM ILLUMINATION ON DISTANCE VISUAL ACUITY USING A PROJECTED CHART

By

James Kundart

and

Milo Hatch

A thesis submitted to the faculty of the College of Optometry, Pacific University, Forest Grove, Oregon

for the degree of
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Advisor:

Suzanne D. Scott, O.D.
THE EFFECT OF ROOM ILLUMINATION ON DISTANCE VISUAL ACUITY USING A PROJECTED CHART

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James J. Kundart received a Bachelor of Science degree in Astronomy and Astrophysics and a Bachelor of Arts in History from the Pennsylvania State University in 1993. He is a candidate for a Masters of Education, Visual Function in Learning and a Doctor of Optometry degree from Pacific University in 1999. James proudly serves as the National Student Liaison to the College of Optometrists in Vision Development for the 1998-99 school year. He plans to establish a specialty vision therapy practice in Bethlehem, Pennsylvania after completing a residency. His family includes Suzanne Peppell, a Naturopathic Physician candidate (1999) and three housecats.

Milo W. Hatch received a Bachelor of Science degree in Biochemistry from Washington State University in 1995. He is a candidate for the Doctor of Optometry degree from Pacific University in 1999. He is a member of Beta Sigma Kappa Honor Fraternity and the College of Optometrists in Vision Development. Milo hopes to pursue a residency and career in hospital-based optometry. In his spare time he enjoys drawing, playing classical piano and reading the great books. He would like to practice optometry in his home state of Idaho.
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ABSTRACT

Historically distance visual acuity (DVA) has been measured in darkened conditions and the assumption has been that different exam room illuminations do not affect DVA in individuals. Recently, there has been some evidence that a particularly dark exam room may degrade acuity in some individuals. This DVA degradation in healthy individuals could be due to night myopia effects or increased optical aberrations. However, a bright exam room may cause reduced chart contrast resulting in lowered DVA as well. The purpose of this study was to determine whether changes in general room illumination can have a significant affect upon DVA.

In this study, the DVA’s of 37 healthy subjects between the ages of 12 and 49 were measured at three statistically different room illumination levels (300-440 lux, 100-200 lux, and 1-50 lux, p=0.0001) with a projected Flom (or S-) chart. The three subject groups mean DVA’s for the three room illumination levels were compared using ANOVA repeated measures test. No significant differences were found between the three mean DVA’s (LogMAR -0.078, -0.097, and -0.100 at bright, medium, and dim lighting levels respectively, p=0.234). This suggests that DVA was not affected by changes in general room illumination. However, there was a small subgroup of subjects whose DVA was significantly reduced at the lower room illuminations. The possibility that these subjects represent a clinically significant subgroup of patients who are night myopes is explored.
KEY WORDS

Distance visual acuity (DVA), night myopia, room illumination.

INTRODUCTION

Visual acuity is a paramount measurement in the visual sciences and a skill around which much of society operates. Distance visual acuity (DVA) often serves as a method for tracking changes in refractive error or ocular pathology. DVA standards are used to determine qualification for driving and certain careers. DVA is often used for inter-physician communication as well, and can determine insurance and social service eligibility for the partially sighted.

Since DVA testing is a vital societal and medical testing procedure, it would seem important to maintain certain examination room standards during the testing of DVA. While chart contrast and luminance standards exist, room illumination is not usually specified. This is because when it comes to patients with healthy visual systems, many vision scientists like Dr. Merton Flom argue that varying room illumination has an insignificant effect on DVA results. Yet recently others have questioned the role of illumination considering tonic accommodation and pupil size.

One reason that room illumination has no widely accepted parameters is because it is indirectly defined by the standards for chart luminance and contrast. Sheedy recommends keeping chart
luminance between 80 and 320 lux during projected chart DVA measurement, ideally at 160 lux. Luminance is mostly dependent on the clarity of the projector's optical surfaces, the condition of the lamp and the position of the reflector screen. Concerning chart contrast, Grosvenor recommends at least 90%. To meet the latter criterion many examiners keep ambient illumination in the exam room to a minimum. This protocol may have the further advantage of directing patient attention to the chart, the only bright spot in a dim exam room.

On the other hand, there are compelling reasons to use brighter exam room illuminations when measuring DVA. It is well established that decreased room lighting levels will affect DVA in certain populations, such as patients with lenticular changes, retinitis pigmentosa and amblyopia.

Most of the previous studies dealing with DVA and photometry have examined chart luminance rather than room illumination effects. The changes in luminance have been standardized by using neutral density (ND) filters in front of the subjects' eyes. To eliminate optical aberrations brought on by a larger pupil, traditional studies have also employed artificial pupils in the form of calibrated apertures.

For all the advantages of these standardized techniques, there are disadvantages as well. Often these studies use screens around the ND filters which block peripheral light stimulus. Gallup has
argued that the loss of peripheral stimulus alone will negatively affect DVA in some patients. Also, the effects of an enlarged pupil including peripheral aberrations, size of the exposed retinal mosaic and the pupil’s link to accommodation by the near triad are not clinically irrelevant.\textsuperscript{1,18,19}

Very few studies have investigated the effect on DVA when chart contrast and luminance are held constant while exam room illumination is varied. One notable exception is an undergraduate thesis paper (Glover and Kelly) where 50 subjects were tested with constant chart luminance and contrast at two illumination levels (bright and dark, lux value not specified) inside a specially designed "light box."\textsuperscript{9} Results showed a mean visual acuity of LogMAR -0.8 (20/15-1) with full illumination and LogMAR 0.0 (20/20) with no room illumination, a statistically significant difference in DVA to the p=0.05 level. The fact that the Glover and Kelly study showed a definite change in DVA with changing illumination supports the need for this project. The purpose of the present study is to determine if changes in general room illumination can have a significant effect on DVA in a clinical setting.
The Effect of Room Illumination on DVA Using a Projected Chart

James Kundart
Milo Hatch

METHODS

Subjects

A total of 47 subjects, aged 12 to 49, were tested during this study. Most of the subjects were members of the student body, faculty, and staff of a naturopathic medical school. To qualify for the study, subjects needed to have 20/20 DVA, either through their habitual lenses or through habitual lenses and a pinhole occluder. Entering DVA was measured on a non-projected (paper) Snellen Chart.

All subjects were categorized as either myopes or nonmyopes. The categorization of patients into these two refractive subgroups was done based on entering Snellen DVA for subjects who did not wear habitual lenses, or through neutralization or examination of the subject's habitual lens correction for those who did.

Prior to testing, each subject filled out an informed consent form and subject data sheet. In addition to refractive status, data collected for each subject included age and gender.

Design and Procedures

Subjects were tested in a room equipped with a Kodak Extragraphic slide projector equipped with an Ushio EXR projector lamp (82V, 300 W). The Flom (or S-) chart was used in the form of
21 projector slides for determination of DVA. The Flom Chart was chosen because of its clinical accuracy, LogMAR scale, and resistance to memorization by subjects in repeated testing. Angular subtense of the chart's Landolt rings was calibrated at the beginning of each day of testing. Contrast of the projected letters was measured during the first four days of testing using a Tektronix J-16 photometer. Contrast was maintained at or above a level of 75% by minimizing external and overhead room illumination.

Seating was provided for patients at 20 feet from the chart. Two nearpoint lights were positioned two feet behind the subject to the right and left at the subject's shoulder level. The nearpoint lights were two GE soft white reader lights (4500 lumens and 250 watts each). Variable room illumination was achieved via two rheostats which controlled voltage to the nearpoint lights. Illumination was measured with a Tektronix J-16 photometer and frequently double-checked with a Extech Model 401025 photometer. Illumination was measured at a position midway between the two nearpoint lights at a point directly behind the subject. Subjects wore their standard habitual lenses, if any were worn. All DVA's were taken OU.

After a subject's DVA was determined to be 20/20 or better using a standard paper (nonprojected) Snellen chart, the room illumination was adjusted to one of three illumination ranges (1-50 lux, 100-200 lux, or 300-450 lux) using the variable nearpoint lighting rheostats. For each subject, the order of presentation of the three room illuminations was determined using the Latin Square
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Technique. The subject was given 5 minutes to adjust to the first illumination level and then subject pupil diameter was measured subjectively with a Scheiner Principle Pupillometer as described by Cogan. Pupil size was frequently double-checked objectively with a semicircle pupil gauge. DVA was then taken using the Flom chart slide series.

The Flom (or S-) chart consists of a series of 8 Landolt rings of a specific visual acuity demand arranged in a square with surrounding and central areas filled with tumbling E's for complex contour interactions (Fig. 1). A subject is assumed to have passed a given slide's acuity demand if the orientation of 5 of 8 of the Landolt C's are correctly identified using forced choice. The slides present a range of acuity demands from 20/400 to 20/13 (LogMAR 1.3 to -0.2). The number of Landolt C's the subjects correctly identified on each slide was recorded. Subjects proceeded from the 20/400 acuity demand slide towards the 20/13 acuity demand slide and only stopped when they could no longer identify the orientation of 5 of the 8 Landolt C's on a given slide.

Figure 1 -- The Flom or S-Chart
Once subjects had completed the DVA testing at one light level, the room illumination was adjusted to the next lighting level as determined by the Latin Square Technique. After 5 minutes of pupil adjustment time to the new lighting level, pupil diameter was measured, and the DVA testing was repeated at the new lighting level.

At completion of DVA testing at all three lighting levels, subjects were asked which illumination level they preferred for identifying the Landolt rings on the Flom chart. This completed the data collection for each subject. Total time for testing was approximately 45 minutes.

RESULTS

Contrast and Luminance Data Analysis

In this study, chart luminance and contrast were maintained at relatively high and constant levels to match standards mentioned in the literature. Sloan\textsuperscript{17} and Grosvenor\textsuperscript{10} have recommended minimum chart contrast levels of 84\% and 90\%, respectively. Clinically, many optometrists use a minimum 75\% contrast level. Concerning luminance, Sheedy\textsuperscript{16} recommends from 80-320 lux. In this study chart contrast and luminance were maintained at or near these levels. See Table 1, below.
Chart contrast and luminance data were taken on the first four test days to determine if these lighting parameters were being maintained at a reasonable level. On all but one of these test days, contrast was maintained at or above 75% by limiting the amount of illumination that entered the room from external sources. The low contrast data from day 1 were not used except for one subject's data set, which was kept because it met all other criteria for reliability in this study. Contrast and luminance data were not collected after the first four test days due to confidence on the experimenters' part that they were being maintained at a relatively constant and adequate level.

**Subject Mean Age and Standard Deviation**

Subject mean age was 30.5 years and the standard deviation was 8.5 years. The youngest subject was 12 years of age and the eldest was 49 for a total age range of 37 years. Only 9 subjects were older than 35 years of age, indicating the majority of subjects probably had adequate accommodative amplitude and thus
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Theoretically could have been subject to night myopia effects at low illumination levels.

The data for 10 of the original 47 tested subjects were discarded either because data collection was incomplete or because illumination levels used were outside the range eventually used in the study. The analysis that follows is for the remaining 37.

Comparison of the Three Room Illumination Levels

As indicated on Graph 1 and Table 1A, the means of the three room illumination levels used were significantly different \((p=0.0001)\) as shown by a Statview ANOVA repeated variables analysis of the illumination level data. This indicates small variations in illumination levels used for each subject were not statistically significant for the group as a whole.
The central question of this study was whether DVA is affected by room lighting level. Table 2 and Graph 2 indicate that although the group data show an improvement in DVA with dimmer room illumination, this change is not statistically significant (p=0.234). Analysis was done with a Statview ANOVA repeated variables test. Change in LogMAR DVA between brightest and dimmest
illuminations was also examined using a paired t-test. The mean change was found to be only LogMAR 0.022, which was also statistically insignificant (p=0.1032).

Table 2: DVA Changes and Room Illumination

<table>
<thead>
<tr>
<th>Illumination Level</th>
<th>Mean LogMAR DVA</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bright</td>
<td>-0.078</td>
<td>0.162</td>
</tr>
<tr>
<td>Medium</td>
<td>-0.097</td>
<td>0.128</td>
</tr>
<tr>
<td>Dim</td>
<td>-0.100</td>
<td>0.125</td>
</tr>
</tbody>
</table>

Graph 2: DVA Changes and Room Illumination

All Subjects (n=37)
Subjects were broken down into two subgroups based on refractive error (myopes/nonmyopes). Data for myopes (n=26) were analyzed using a Statview ANOVA repeated variables test to determine if these subjects experienced a more noticeable effect on DVA from differences in room illumination than the subject group as a whole. The myopic subgroup showed no significant effect on DVA from changes in room illumination (p=0.436). The slight improvements seen in LogMAR DVA on Table 3 and Graph 3 with dimmer room illumination are again not significant due to the large standard deviations associated with the DVA measurements.

Table 3: DVA Changes and Room Illumination

<table>
<thead>
<tr>
<th>Illumination level</th>
<th>Mean LogMAR DVA</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bright</td>
<td>-0.058</td>
<td>0.181</td>
</tr>
<tr>
<td>Medium</td>
<td>-0.078</td>
<td>0.14</td>
</tr>
<tr>
<td>Dim</td>
<td>-0.081</td>
<td>0.139</td>
</tr>
</tbody>
</table>
Graph 3: DVA Changes and Room Illumination

Myopes (n=26)

DVA Changes and Room Illumination -- Nonmyopes (n=11)

Nonmyopes were analyzed using Statview in the same manner as myopes. Like the myopic subgroup, nonmyopes (n=11) showed no significant change in LogMAR DVA with changes in room illumination (p=0.3259). Table 4 and Graph 4 also show no consistent trend in DVA change with change in room illumination.

Table 4: DVA Changes and Room Illumination

<table>
<thead>
<tr>
<th>Illumination level</th>
<th>Mean LogMAR DVA</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bright</td>
<td>-0.127</td>
<td>0.090</td>
</tr>
<tr>
<td>Medium</td>
<td>-0.155</td>
<td>0.069</td>
</tr>
<tr>
<td>Dim</td>
<td>-0.145</td>
<td>0.069</td>
</tr>
</tbody>
</table>
The Effect of Room Illumination on DVA Using a Projected Chart

Graph 4: DVA Changes and Room Illumination

Nonmyopes (n=11)

Pupil Diameter and Room Illumination (n=37)

Using a Statview ANOVA repeated measure test, pupil diameter changes with changes in room illumination were found to be significant (p=0.0001) as indicated by Table 5 and Graph 5. As can be seen from the table and graph, pupil diameter increased with dimmer illumination as expected.

<table>
<thead>
<tr>
<th>Illumination Level</th>
<th>Mean Diameter (mm)</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bright</td>
<td>4.516</td>
<td>0.954</td>
</tr>
<tr>
<td>Medium</td>
<td>4.859</td>
<td>1.049</td>
</tr>
<tr>
<td>Dim</td>
<td>5.164</td>
<td>0.95</td>
</tr>
</tbody>
</table>
The Effect of Room Illumination on DVA Using aProjected Chart

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Milo Hatch

Graph 5: Pupil Diameter and Room Illumination (n=37)

DVA Changes and Room Illumination -- Selected Subjects

Of all 37 subjects, three subjects demonstrated substantial decrease in DVA with dimmer illumination as shown in Table 6 and Graph 6 below. Using a Statview ANOVA repeated measure test, it was found that this change in DVA for these three subjects was significant (p=0.0494). Interestingly, two of these three subjects were older than 40 years of age but showed no abnormal trends in pupil size. These subjects' data will be examined further in the Discussion section, below.

A similar analysis was run on the three subjects that demonstrated the most substantial degradation of DVA with brighter
illumination, but the analysis showed that this degradation in DVA was not significant to the 0.05 level ($p=0.156$). These subjects were mostly younger than 30 years of age and again showed no abnormal trends in pupil size.

There were also eight different subjects whose entering acuities were not corrected to 20/20 (while still reaching 20/20 through a pinhole occluder). For these eight, there was no statistically significant difference in DVA between the three room illuminations when calculated to the $p=0.05$ level.

**Table 6: DVA Changes and Room Illumination**

<table>
<thead>
<tr>
<th>Night Myopes? (n=3)</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Illumination level</th>
<th>Mean LogMAR DVA</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bright</td>
<td>-0.100</td>
<td>0.058</td>
</tr>
<tr>
<td>Medium</td>
<td>-0.067</td>
<td>0.088</td>
</tr>
<tr>
<td>Dim</td>
<td>0.000</td>
<td>0.058</td>
</tr>
</tbody>
</table>
Graph 6: DVA Changes and Room Illumination

Night Myopes? (n=3)

DVA Changes and Room Illumination Based on Age

Subjects were also analyzed by age for changes in DVA. Subjects were categorized into a 35 and older category (n=10) and a younger than 35 category (n=25). Two of the 37 subjects declined to give their age and were thus omitted from this analysis.

Mean entrance DVA's as measured on the nonprojected (paper) Snellen chart were 20/20-2 for the pre-presbyopes and 20/20 exactly for the 35 and older group. In fact, all subjects in the older group had entering DVA's of LogMAR 0.00 (20/20), while there were 7 pre-presbyopic subjects who had less than 20/20 entering acuity. The mean age of the pre-presbyopic group was 26.2 years. For the 35 and older group it was 41.3 years.
The mean DVA of each age group was analyzed separately using a t-test to determine if significant changes in DVA occurred between the bright and dim room illumination levels. No statistically significant changes in DVA were found within either subject age category as room illumination was changed. However, there was a significant difference in overall DVA between the younger and older age categories, with the older subjects having substantially (1 to 1.5 Snellen lines) better acuities than the younger subjects (Graph 7). This issue will be dealt with further in the Discussion section, below.

**Graph 7: DVA Changes and Room Illumination Based on Age**

Subjective Preference of Subjects for Room Lighting Level:

As can be seen in Graph 8, more subjects preferred brighter room lighting levels for reading of the Flom (or S-) chart. This
preference occurred despite the fact that DVA's at the three room lighting levels were not statistically different from one another.

Graph 8: Subjective Preference of Room Illumination Level

DISCUSSION

Overall, this study showed no statistically significant effect of changes in room illumination on binocular DVA in the subjects tested. This conclusion was the same when the myopic and non-myopic subgroups were analyzed separately. As expected, pupil size did increase with decreasing room illumination. A statistically insignificant trend was seen towards improvement of DVA with a decrease in room illumination. Paradoxically, more subjects preferred the brightest room lighting level over midrange or dimmer lighting.

Three of the 37 subjects in the study showed a one-line or more decrease in DVA with decreased room illumination, significant to the $p=0.05$ level. (see Table 6 and Graph 6). An argument can be
made that these subjects represent nothing more than random variation within the larger sample. At the p=0.05 level, about two of the 37 subjects would be expected to show a significant change in DVA by chance alone.

However, clinically speaking, could these subjects be the elusive night myopes? As was noted above, two of the three subjects were over age 40. This raises the suspicion that normal age-related changes in media clarity may have given rise to the decrease in DVA under dim illumination. Since a pinhole occluder was the only screening used for ocular pathology, brunescence of the lens remains a possibility.

The decreased DVA of the pre-presbyopes at all lighting levels is not difficult to explain. Pseudomyopia is one likely culprit. Some incidence of pseudomyopia might be expected in this younger population of graduate students with a heavy near point work load. There could also be an economic factor involved, since most of the younger subjects were graduate students and less likely to have current prescriptions than the more affluent older subjects, who were mostly faculty and staff of the College at which the testing was done.

Returning to the literature, most of the previous studies on this subject use neutral density (ND) filters and/or artificial pupil apertures in front of the subject to simulate changing illumination. This method is convenient and repeatable but has some qualitative
differences to the way the present study was done. For example, when looking through a ND filter, a subject experiences decreased chart luminance as well as decreased room illumination, among other differences discussed in the introduction.

By changing room illumination instead of using ND filters and artificial pupils, the present study kept projected chart luminance constant in order to investigate other potential influences on visual acuity. In the present study changes in subject pupil diameter did occur and may induce peripheral aberrations, but these same aberrations would occur inside and outside the typical exam room. Even though low room illumination may have lead to some induced optical aberrations in this study, this may not be a flaw so much as a way to tease out illumination-driven differences in DVA. More studies of this kind are needed.

In a rare example, Glover and Kelly\(^9\) at the Australian College of Orthoptics conducted a fascinating undergraduate thesis study which is elaborated upon here because of the difficulty the reader may have in accessing the paper. Glover and Kelly used a custom "light box" with a Snellen chart of nonprojected letters. Fifty randomly chosen subjects (100 eyes) were included in the study. The subjects' age range was from 18 to 58, with a mean age of 25.8. Subjects were screened for aphakia, cataracts, accommodative dysfunction, strabismus, amblyopia, and medications which could affect vision.
Autorefraction was used to determine refractive error. Pupil size was recorded in darkness and in an unspecified light box ambient illumination. The study found that even with changing Snellen charts to prevent memorization, most subjects had significantly better VA in the brighter illumination. The acuities differed by almost a Snellen line (from 20/15-1 in the bright condition to 20/20+1 in the dark), and so were clinically relevant.

Of previously done research, the Glover and Kelly study is most similar to the present one in that it looked at pure effects of illumination changes on DVA. The main difference was that the present study used an open room and full 20' testing distance and nearpoint lighting, rather than a closed box with its associated proximal effects. Perhaps this is the reason the results of the two studies do not correlate. Be that as it may, both studies were more clinically accurate in terms of avoidance of neutral density filters and artificial pupils. More of these clinical studies need to be done to verify the night myopia effect and to find a good way to identify responders.
In retrospect, the present study has some weaknesses which could be avoided in future research. One of these is the difficulty of keeping the contrast of the projected chart above the 84-90% needed to measure DVA accurately. During one research day contrast fell below this level due to use of ceiling lights rather than double room lighting. The clinician interested in avoiding night myopia effects should, in most exam lanes, use the nearpoint light rather than ceiling illumination if possible. Alternately, one could use a "chart" immune to contrast reduction, such as a Binocular Visual Acuity Tester (BVAT) or similar computer monitor.
REFERENCES


