

The Effect of Room Illumination on Visual Acuity Measurement

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Abstract

Although a number of parameters have been standardized when testing visual acuity (including chart distance, optotypes and luminance of the chart), there is considerable variation in room lighting conditions used. Currently no research exists which either suggests a particular room illumination, or even if there is any difference in visual acuity with different room lighting conditions. The purpose of the current study was to determine whether changes in room illumination affect the level of distance visual acuity recorded. Visual acuity was randomly tested on 50 subjects (98 eyes) using the standard Snellens chart in two different room illumination levels, with normal room illumination (with room lights on - 1300 lux) and with reduced room illumination (with room lights off - 90 lux). Residual refractive error (difference between spectacle correction and autorefractometry) was calculated and pupil size measured in each condition. Overall a significant difference in visual acuity between the two lighting conditions was

found with visual acuity levels improving with room illumination (6/9+4 in illuminated room, 6/9+2 in non-illuminated room; $t=4.653$, $p<0.001$). The difference was found to be greater in the non-emmetropic group (6/12+3 in illuminated room, 6/12 in non-illuminated room). There was a small subgroup of subjects' eyes where the visual acuity level dropped by more than one line in the non-illuminated room ($n=18$). The reason for this difference may be related to optical influences on visual acuity such as accommodation and night myopia.

Key words:

Visual acuity, illumination.

Introduction

The measurement of visual acuity forms a fundamental part of clinical practice and is an important measure for conducting research into many aspects of the visual system. Visual acuity needs to be performed in a reproducible fashion especially when it is the primary variable used to assess change in visual function over time or after application of a form of treatment. Guidelines for standardizing the measurement of visual acuity have been suggested including recommendations for the type, spacing and number of optotypes, standardizing the chart lighting, instructions for the testing procedure and scoring of the visual acuity result¹, but seemingly little attention has been placed on standardization of the room illumination.

There is a need to define the terms related to lighting levels when testing visual acuity-illumination, luminance and contrast. Illumination refers to the intensity of light falling on a subject and is measured in lux (the international unit of illumination). The illumination on a surface at 1 metre distant from a point source of 1 candela is 1 lumen /m² known as 1 lux. The illumination at 1 foot from a source of 1 candela is 1 lumen /ft² which is equal to 10.764 lux as there are 10.764 square feet in 1 square metre. This was previously known as the foot candle, quoted in the early

literature describing illumination required for the testing of visual acuity prior to the advent of internally illuminated vision charts and projected charts. Illumination of around 12 to 18 foot candles was considered the standard illumination for visual acuity charts.^{2,3} This standard was questioned by several authors who noted that visual acuity decreased with decreasing illumination,^{4,5} and that lower illumination levels were required to detect subtle visual abnormalities such as refractive errors. It was also stated that many occupations required personnel to work in much lower levels of illumination and perhaps the standard should be varied depending on the purpose for measurement of visual acuity.⁴

In the early '80s when the Early Treatment Diabetic Retinopathy Study (ETDRS) was conducted, new visual acuity charts were designed that had a standard progression of letter size and spacing between lines.⁶ These charts are known as the logarithmic Minimum Angle of Resolution (logMAR) chart. Illumination was standardised by either direct illumination (onto the chart externally) at a level of between 807 to 1345 lux or retroilluminated.⁷

With use of retroilluminated charts it became necessary to standardise the luminance of the chart. Luminance refers to the intensity of light emitted from a surface (such as that reflected by an internally illuminated vision chart) and is expressed in "nit", the international unit of luminance, equal to 1 candela per square metre (cd/m^2).⁸ The normal photopic range of luminance is 40-600 cd/m^2 . There is ample evidence to show that there is a reduction in visual acuity as chart luminance reduces.^{9,10,11} Rabin⁹ showed that reducing the luminance from 116 to 0.23 cd/m^2 by using neutral density filters over the subjects' eyes produced a 3 times reduction in visual acuity.

In a study by Sheedy Bailey and Raasch¹¹ the luminance standards across the world were compared and the effect of luminance on visual acuity across a wide range of luminance levels was evaluated. In the photopic luminance range a doubling of luminance levels was found to improve visual acuity by approximately one letter on a five-letter row. They recommended chart lighting to be 160 cd/m^2 with a range of 80-320 cd/m^2 . These are the standards that are also recommended by the United States Food and Drug Administration.¹

A third aspect to be considered when testing visual acuity is the contrast level, which is defined as the ratio between target luminance over target and background luminance. For visual acuity it is recommended that there be "high contrast between optotypes and background".^{1,9,181} Visual acuity is affected when contrast drops below 70% so it is important to keep contrast above this level when measuring visual acuity. The effect of contrast on vision is best evaluated by the use of contrast sensitivity testing procedures. Previous researchers have studied the effect of luminance, age and

refractive errors on visual acuity performance, but not room illumination.^{4,9,10,11,15,16,18,19}

The British Standards Institute specifies a uniform external illumination of at least 480 lux.¹² When a sample of 45 schools were evaluated to determine whether standard conditions were used for visual acuity testing for school screening 89% were found to not be able to meet this illumination requirement.¹³ Researchers conducting multicentre trials have also encountered problems when setting room illumination standards for visual acuity testing. The Scleral-Primary-Rhegmatogenous study (comparing treatment for retinal detachment at 24 centres in Europe) has adopted a level of not greater than 150 lux (H. Heimann personal communication 19th March 1999, M Hellmich personal communication 6th April 1999). Currently practices in Australia use a variety of methods to test visual acuity, many using the standard Snellens chart with varying room illumination. Some practitioners prefer to use fluorescent room lights with others dimming or turning off room lights. The aim of the current research was to evaluate whether different room illumination levels affect the measurement of visual acuity.

Method

1. Subjects

A total of 50 subjects (98 eyes) was chosen from the population available to the researchers, and mainly consisted of fellow students and staff at the Faculty of Health Sciences, University of Sydney. The age ranged from 18 to 58 years with a mean age of 26 yrs, SD of 12.3 years. Nine of the subjects wore glasses. Recordings were excluded if any of the following were present: aphakia, cataract, anomalies of accommodation, medication that may affect visual acuity, the squinting eye in strabismus and amblyopia.

2. Testing Procedure

Before testing, each subject was asked about their ocular history to determine if they were suitable for the study. The uncorrected refractive error of each subject was obtained objectively using the Humphrey Autorefractor (Hark Model 599). When glasses were worn the prescription was determined using a Topcon LM-P6 vertometer, and the difference between the glasses prescription and autorefraction results was recorded as the residual refractive error. For example for glasses of -2.00, and an autorefraction recorded -2.50; a residual refractive error of -0.50 was calculated.

Visual acuity was measured monocularly in the same room under the same testing conditions for all subjects. The luminance of the vision box was in the range of 180 to 220 cd/m^2 produced by two 40 watt pearl light bulbs. A chart and lighting system enclosed in a wooden box was used so that extraneous light did not interfere with the results.

Vision was tested at 6 metres using two Snellen charts in a random order to eliminate any learning effect. The subjects were randomly placed in one of two lighting conditions: an illuminated room with the room lights on (1300 lux) and a non-illuminated room with the room lights off (90 lux). Outside light was completely eliminated. Visual acuity was measured using standard instructions and pupil diameter was also measured. Subjects who wore glasses were tested while wearing their glasses. The Snellens chart was changed and alternative room lighting was used and again pupil diameter was measured. Subjects were given one minute to adapt to the new conditions prior to testing their visual acuity. Subjects were then asked to comment on which lighting condition they preferred.

3. Analysis

For the purpose of statistical analysis the subject's refractive error (autorefraction results in the case of non-glasses wearers, residual refraction for glasses wearers) was converted into the spherical equivalent. The mean residual refractive error was -0.61D with a range of -4.88D to +1.19D.

Snellens acuity scores were converted to a decimal equivalent ranging from 1 (6/60) to 8 (6/5). (See Table 1 for these conversions.) This conversion produced a pseudo-linear scale for statistical analysis.

A paired t test and ANOVA were used for statistical analysis. It should be noted that although a number of statistical tests were undertaken, a very high level of significance was obtained. Therefore no adjustment was made to control for the family-wise error rate.

Results

1. Overall difference in visual acuity

A paired t test showed that there was a significant difference between visual acuity in the two lighting conditions ($t(97) = 4.653, p < 0.001$). The mean visual acuity in the illuminated room was greater than in the non-illuminated room. Table 2 shows the overall means and their standard deviations. The SD was large as there was a large range in visual acuity levels recorded; from 3/60 to 6/5.

2. Pupil size

Pupil size increased in the non-illuminated room; mean pupil size in the illuminated room was 3.3mm SD 0.79, and mean pupil size in the non-illuminated room was 4.8mm SD 1.1. This difference was also found to be significant ($t(97) = -12.084, p < 0.001$).

Snellen Acuity	Letters on the Snellen Chart							
	1	2	3	4	5	6	7	8
6/60	1							
6/36	1.5	2.0						
6/24	2.33	2.67	3					
6/18	3.25	3.5	3.75	4				
6/12	4.2	4.4	4.6	4.8	5			
6/9	5.17	5.33	5.49	5.65	5.81	6		
6/6	6.14	6.29	6.43	6.57	6.71	6.86	7	
6/5	7.125	7.25	7.375	7.5	7.625	7.75	7.875	8

Table 1.
Conversion scale for Snellen Acuity Chart.

Group	Mean VA in illuminated room	Standard Deviation	Mean VA in non-illuminated room	Standard Deviation
All subjects	6.57 (6/9+4)	2.2	6.3(6/9+2)	2.3
Emmetropes	7.45 (6/6+4)	1.5	7.4(6/6+3)	1.5
Non-emmetropes	5.53(6/12+3)	2.4	5.01(6/12)	2.4
Hypermetropes	7.48(6/6+4)	1.01	6.95(6/6)	1.02
Myopes	5.29(6/12+2)	0.36	4.77(6/12-1)	0.36

Table 2.
Mean visual acuity for all groups in the illuminated and non-illuminated room.

3. Effect of refractive error

Residual refractive error was examined in two ways. Firstly emmetropes and non-emmetropes were compared, and secondly the non-emmetropic group was divided into hypermetropes and myopes and then compared.

3.1. Emmetropes and non-emmetropes

Subjects with a spherical equivalent refractive error between +0.50 and -0.50 were classified as emmetropes (n=53) and all others non-emmetropes (n=45). A significant interaction existed between emmetropes and non-emmetropes across the illuminated room and non-illuminated room conditions ($F(1,96)=18.699$, $p<0.001$, Figure 1). Post-hoc analysis revealed that no difference existed between the lighting conditions for the emmetropes, but a significant difference occurred across lighting conditions for the non-emmetropes ($t(44)=5.964$, $p<0.001$). Visual acuity was greater in this group in the illuminated room condition, over the non-illuminated room condition (Figure 1, Table 2).

3.2. Myopes and hypermetropes

To determine if the type of refractive error influenced the visual acuity results in both conditions the non-emmetropic group was then divided into myopes, subjects with a spherical equivalent greater than -0.50 (n=40) and hypermetropes, subjects with a spherical equivalent of +0.50 or greater (n=5). No significant interaction was found between myopes and hypermetropes across room illumination. A significant effect of the illumination condition was found, with improved visual acuity in the illuminated condition over the non-illuminated condition ($F(1,43)=13.614$, $p<0.001$; Figure 2, Table 2). Although a significant effect of myopes versus hypermetropes was found, the degree of effect was marginal ($F(1,43)=4.142$, $p=0.048$; Table 2). This low level of effect may have been due to the small number of hypermetropes. Further, without correction for the family-wise error rate this result should be considered as a possible artifact.

Figure 1.

Mean visual acuity for emmetropes and non-emmetropes in both lighting conditions.

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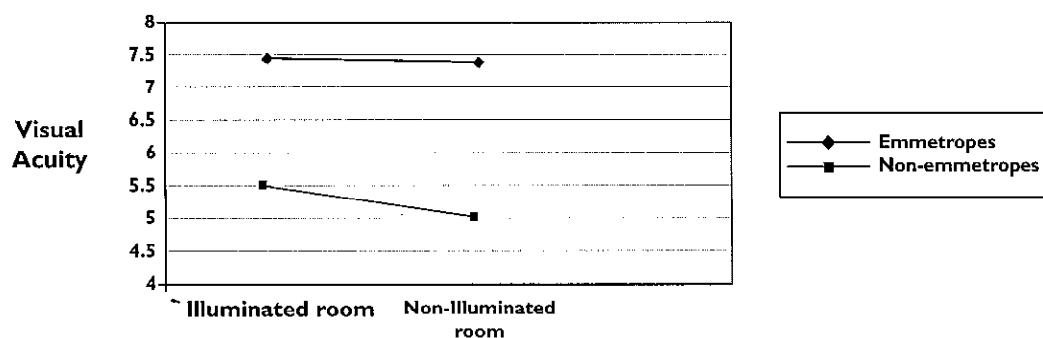
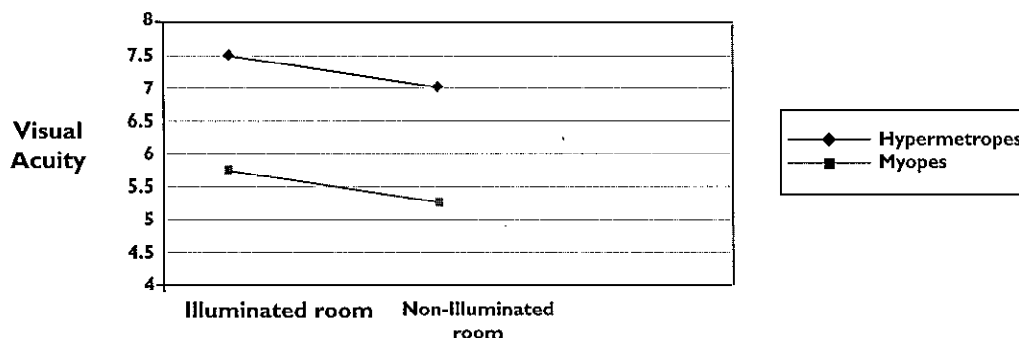


Figure 2.

Mean visual acuity for hypermetropes and myopes in both lighting conditions.



4. Selected cases

There were 19 eyes that showed a greater than 1 line change of visual acuity between conditions with all but one showing a decline in visual acuity in the non illuminated condition. These cases did not significantly differ from those where there was a less than one line difference in visual acuity when age, pupil diameter and residual refractive were compared. It appears that there is a small but important subset of subjects where visual acuity can be more profoundly influenced by changes in room illumination.

5. Subject preference

Subjects were asked to comment on which lighting condition they found better or easier to see the letters. Seventy eyes of the subjects preferred the room lights on, fourteen found no difference between lighting conditions and fourteen preferred the room lights off.

Discussion

Overall the current study found a statistically significant difference in visual acuity between the two lighting conditions with visual acuity levels improving with room illumination. The difference was found to be greater in the non-emmetropic group. The difference found was small, around 4 letters on the Snellens chart, so there is some question as to the clinical significance of this result. Considering the variable nature of measuring this psychophysical function one may expect a variation of plus or minus one letter on a five-letter row.¹¹ However, it does appear that there is a small but important subgroup of subjects where room illumination will affect the visual acuity level recorded with over one line of worsening in dimmer illumination.

Recently (following completion of the collection of data for the current study) Kundhart and Hatch examined the visual acuity of 37 normal subjects using a projected chart in three different room illumination levels 300-440 lux, 100-200 lux and 1-50 lux.¹⁴ No significant difference was found between mean visual acuity in the three lighting levels (logMAR -0.078, -0.097 and -0.100 at bright, medium and dim lighting levels respectively, $p=0.234$). In fact a slight improvement in visual acuity was found in dim lighting conditions contrary to the current study. This difference in results may be because the researchers measured visual acuity binocularly using a projected logMAR chart and all subjects had 6/6 visual acuity. Interestingly they also found a small subset of 3 subjects with a one-line or greater reduction of visual acuity with decreased room illumination.

The difference in visual acuity found between the two lighting conditions in the current study may be due to optical factors including pupil diameter, refractive error and accommodation. The decrease in visual acuity in the non-illuminated room could be

accounted for in part by the dilation of the pupil. Pirenne¹⁵ however, using artificial pupils and more recently Rabin⁹ using natural and artificial pupils, showed that the reduction in visual acuity in lower luminances was the same regardless of pupil size.

In this study there did appear to be a relationship between the visual acuity in the non-illuminated room and the presence of a residual refractive error, with visual acuity worse in the non-emmetropic group. Others have also found this result. For example Ferree^{4,247} using very small simulated astigmatic errors of only 0.25 dioptres found a "readily detectable" difference at low illumination levels. In addition Johnson and Casson¹⁰ using a larger simulated range of refractive errors up to 8 dioptres found that the effect of luminance, contrast and blur on visual acuity was additive. A larger effect on visual acuity was found with dioptric blur up to 2 dioptres and a more gradual reduction in visual acuity with dioptric blur over 2 dioptres. The reason for this apparently worse visual acuity result for non-emmetropes in lower illumination levels is unclear. One possibility may be related to accommodation. Jiang, Kenneth, Herschel¹⁶ stated that when luminance is lowered accommodation tends to shift toward different and individually characteristic resting potentials commonly known as dark focus. This position is not a static one and can vary depending on the type of refractive error and is biased towards the last accommodative position. Many of the subjects tested in the current study were university students with a larger than normal near point work load. This may have contributed to a "night myopia" effect which would reduce visual acuity levels in the non-illuminated room. Further research would need to more closely examine this effect.

Although the differences in visual acuity found in the two different illumination levels were small, it remains to be seen whether this effect would be maintained in a different population. All subjects tested were considered to have no ocular abnormalities. What might be the case in a population with ophthalmic abnormalities or with an older population? It is known that patients with age related macular degeneration have difficulty performing acuity tasks at lower luminances¹⁷. Anisometric amblyopes also record lower visual acuity levels than strabismic amblyopes at reduced luminance levels.¹⁸ Sturr, Kline and Taub¹⁹ compared the ability of younger (18 to 25 years) and older (60-87 years) subjects to reach the 6/12 acuity level in varying luminances. At lower luminances a much smaller proportion of the older subjects were able to meet the 6/12 acuity standard (required for driving). They suggested that daytime acuity was a poor predictor of low illumination acuity. While all these researchers were evaluating luminance of the chart and not room illumination levels, each can be considered to be influencing the contrast of the visual acuity chart and ultimate visual acuity recorded.

Conclusion

There appears to be small reduction in visual acuity when tested in a non-illuminated room, which is greater (around 3 to 4 letters on a Snellens chart) for subjects with an uncorrected refractive error. Although this may be considered a tolerable error inherent in measuring any psychophysical function, consideration should be given to standardizing such illumination in clinical populations.

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