Effects of testing distance on visual acuity measures

Visual Acuity is one of the most important baseline examinations of any ophthalmic investigation; however the method of carrying out this test varies between clinicians from chart type to distance of testing. There is limited evidence available correlating the results of measurements between these distances. This student will establish a comparison of Visual Acuity (VA) measurements at 3 meters and at 6 meters. It will also examine if any differences found can be related to disease processes, refractive errors or other visual problems.

METHODS: A cross sectional study of 490 participants from ages 5 to 89 was conducted from a sample of convenience taken from hospitals, clinics, family and friends and various community groups. Visual Acuity Measurements were determined at the viewing distances of 3 and 6 meters using charts based on the logarithm of the angle of minimum resolution (logMAR) principles.

RESULTS: VA results taken at 6 meters and 3 meters were found to be correlated (right eye (RE) – 0. 840, left eye LE – 0. 850 p= 0. 01), these results were consistent across all refractive errors. When near visual acuity (NVA) and distance visual acuity (DVA) were compared there was a high coefficient of determination (RVA R^2 = 0. 706, LVA R^2 = 0. 722). It was also found that acuity measurements dropped with increasing age, independent of distance.

CONCLUSIONS: VA measures taken at distances beyond 2 meters are directly comparable and should show consistent values independent of the

distance. Diseases and refractive errors were not shown to impact on the VA results at different distances.

INTRODUCTION

Visual Acuity is the gold standard test of visual function; accurate examination and recording of VA is essential for the purpose of diagnosis and monitoring of disease progression1. It is defined as the minimum angle of resolution corresponding to the smallest detail that can be identified by the spatial resolution of the visual cortex2. To obtain reliable and reproducible results, several conditions need to be considered including contrast3, 4 , illumination5, patient co-operation6 and testing distance7.

The Visual Acuity Measurement Standard set by the International Council of Ophthalmology agrees that there is no single uniform accepted testing distance, however has suggested that the standard distance is 4m or over with mirror systems being accepted. Practitioners use rooms that vary in size, with most using mirrors as compensation as few clinics are built to accommodate the 4 or 6 metres needed10. Despite the variable testing distances the most commonly used chart is the Snellen which was designed for use at 6 metres11.

It has been established that there is a deficiency in the design and format of the Snellen leading to poor repeatability of results. The disparities in results have been identified as a culmination of various factors including background illumination of chart, variation of numbers of optotypes on each line, contour interaction and irregular progression of letter sizing11-14. As such, modifications have been made to improve on these deficiencies.

In 1959, Louise Sloan thoroughly reviewed procedures of testing visual acuity and as a result devised a set of non-serif letters; these were chosen for their complexity and ability to test acuity in all meridians in order to address potential undercorrected astigmatism15. Soon afterwards, Bailey and Lovie introduced a new chart consisting of proportional spacing with five letters on each line still using a logarithmic progression. This standardised the contour interaction or ' crowding effect' as well as the number of errors that could be made per line. This method of visual acuity scoring through the logarithm of minimum angle of resolution progression is known as the logMAR principle. 16

These features were then combined in order to establish a standardised method of measuring visual acuity for the Early Treatment of Diabetic Retinopathy Study (ETDRS). This chart consisted of proportional spacing, geometric progression, san-serif letters and five letters per line and has been set as the International Standard. 17 Charts based on LogMAR principles are superior in reliability and accuracy and were designed for use at different distances with the only variable being the change in angular size of letters12. This allows for more accurate testing in patients where a closer testing distance is needed such as children or patients with low vision18.

However there is few supporting evidence available that compares the visual acuity measurements at 6 metres and a closer distance on any singular group of subjects. This begs the question to whether VA measurements taken at different distances are directly comparable and if so whether any differences found may be impacted by ocular problems such as refraction or disease processes.

Refractive errors will present different VA results depending if the testing distance is within its far point and near point. An under corrected or uncorrected myopic patient will show a decrease of visual acuity if the image is brought beyond its far point, whereas a hypermetrope however may present as enmetropic due to the ability to overcome their refractive error and bring the image into focus through accommodation. It is this mechanism that determined the traditional use of the 6m testing distance as it is considered that at this distance any further accommodation exerted will not provide additional clarity of the image. Change of testing distance in particular closer to the patient requires an increased exertion of accommodation, those with presbyopia, a reduction in the ability to accommodate due to age will also yield reduced VA results. 19-21

Although near visual acuity (NVA) is not the focus of this study, we will also be comparing the results with the measurements at 3 and 6 metres. In certain subjects NVA will be indicative of the distance vision, however in participants with presbyopia this is expected to be reduced22.

Another age related change that may account for reduced VA results in the elderly are cataracts. Different types of cataracts have impacts on VA of varying distances; nuclear cataracts have been known to result in myopic shifts which could lead to reduced distance VA whereas posterior cataracts can have reduced near VA because of opacities in the central location of the lens. Although starts on the periphery of the lens and can cause astigmatic shifts, the reduced vision has been found to be independent of the testing distance. 23-26

Young children are another population group in which the testing distance has a great impact upon the VA results obtained[27]. Visual acuity for young children and infants are measured using behavioural techniques such as preferential looking and clinical measurement of letter acuity is not commenced until the child of a cognitive level to co-operate with the clinician. A review of the methods utilised to test children showed that the Snellen chart is most useful as logMAR adaptions have not been made for children, it also showed that there was an improvement in results when VA was tested at 3 meters[6].

Aside from co-operation and cognitive ability, young children still have developing visual systems and visual acuity results improve from the age of 1 to a peak at the age of 5[30]. Despite the maturing of the visual system, improved condition VA results is still dependent upon testing distance as it has been shown that children do better at testing at around 1-2 metres although this has been attribute to psychological reasons rather than physiological[18].

Previous studies that have looked at visual acuity measures in relation to distance have found significant changes in distance from 10m to 5m and from 6m to 3m. However aside from this it seems that there minimal evidence examining differences in testing visual acuity at different distances, the purpose of this study is to investigate VA measures at clinically significant distances (3m and 6m) to see if they are able to be directly comparable and relate any differences or trends to visual disturbances, ocular pathologies and refractive error. Factors to consider that may

confound the results, which are not physiological or disease based include patient memory or learning curve, contrast of chart and illumination of room.

METHODS

A total of 490 participants from various clinics and members of the community between the ages of 5 to 89 were evaluated by 49 final year Sydney University Orthoptic Students. Exclusion criteria were illiteracy, age (<5) and vision less than 6/30 VA at 6 m. Each examiner was required to obtain results from 10 participants, 5 < 40 years of age include 2 below 13 years and 5 > 40 years of age.

This study was approved by University of Sydney and conducted under the supervision of Associate Professor Kathryn Rose. It complies with the guidelines of NHMRC and the university's guidelines on ethical research practice. Informed consent was obtained from the participant before examination. In the case of a child under 18, this was obtained from at least one parent and the verbal and/or written consent from the child. Reluctance of a child to undertake testing would override parental consent.

Location of the examination varied from clinic rooms to outdoors in areas of the community. Areas with maximum illumination available and minimal glare were selected for testing conducted outside; all locations were marked with a measuring tape at the distances of 3 and 6m. External environmental factors such as surroundings and sound were consistent throughout the testing.

The participant was examined with their presenting vision, testing first their right eye and then left for the distances 6m, 3 and finally at near. This

allowed for the screening of any participants that did not meet the inclusion criteria (VA > 6/30 at 6 m). To prevent confounding due to a potential learning curve it was suggested that alternative participants had the test conducted on their left eye first. Any refraction correction by glasses or contacts was measured through vertometry if possible, otherwise measurements were reported by the participant; where the participant or their guardian was unsure or unable to report, an estimation of the lens was recorded.

Visual Acuity was determined using the staircase method at 3 and 6 metres with the Good-Lite Sloan Letter Folding Chart (model GL-735000). The eye of the participant that was not being tested was occluded with a patch or occluder and requested to read the first letter of each line starting from the top of the chart; if they were unsure or unable to read the letter they were requested to the read whole line above and progress down the chart until they were unable to see 50% of the line (3/5 letters). Examiners were not allowed to point or isolate any optotypes to maintain the validity of the measurement by preserving the crowding effect.

VA results were recorded as single numerical value that reflected the exact number of letters read correctly on the logMAR chart as quantitative data is better suited for statistical analysis. The participant was awarded 5 letters for each line above the full line they were requested to read under the assumption that if they could read the first letter without hesitation they would correctly answer recognise the rest.

If a Snellen chart was used the type of Snellen chart was recorded as well as whether it was retro-illuminated, projected and whether it included a 7. 5 line along with the total number of letters per line and the number of correct letters identified.

This was then converted into a logMAR equivalence using a formula in the data analysis stage so it could be compared with the other results (see appendix).

To conclude testing, a copy of a reduced Snellen NVA chart using logMAR principles was used to determine near vision. Results were recorded as total number of letters correct, from a maximum of 33 letters. The participant then self-reported any presence of disease processes or ocular conditions that may affect their visual acuity. Guardians were also questioned afterwards for a more accurate understanding.

After the collection of data was complete it was entered into a database through WebCT, the data was the transferred into a statistical analysis program and clean. Analyses were run through two programs, Microsoft Excel 2007 and Statistical analysis system Software (SPSS version 9. 1. 3). Although there was a total of 490 participant results collected, only 475 were included into the dataset as the others were excluded due to missing data. Models, graphs and tables were generated using these programs to show disclose any possible trends or associations between variables. Further use of other statistical analysis were run to evaluate whether these findings were significant and the strength of the associations, tests included T-tests, chi-square analysis, relative risk, Pearson's correlation and ANOVA.

RESULTS

Of the 490 participants examined, only 475 were eligible to be included into the data analysis due to incomplete or erroneous data. The mean age of subjects was 33. 5 years (range 5-89, SD 19. 76) consisting of 269 (57%) women and 206 men (43%). There is a slight disproportion of gender and uneven age distribution skewing towards the younger population which is shown in the below chart, Figure 1. 0

Figure 1. 0

A total of 355 participants wore glasses, with the most common prescription being for near wear (n= 150, 31. 6%). The mean spherical equivalent refraction error of the sample was – 0. 74D with a standard deviation of 1. 90 (range, -17. 0 – 5. 0) Over half the participants (n= 240, 50. 5%) did not wear any type of corrective prescriptions; however it must be noted that not all participants without glasses were refractive error free.

REFRACTIVE ERROR CLASSIFICATION

Subjects had their refractive error classified according to their corrective prescriptions (see Table 1). The majority of participants presented as enmetropes (n= 240, 50. 5%) with the most common spherical equivalent value being between 0 and -1. 0, which is classified as low myopia.

VISUAL ACUITY MEASURMENTS

Statistical analyses was performed on data collected for the distances of 3 and 6, 16 participants had VA measurements recorded using the 6 metre Snellen Chart rather than the preferred logMAR based chart.

The mean VA result obtained for individual eyes is show in Table 2 below, the mean VA for BE at 6 meters was 54. 18 53. 92 (CI 95%, 53. 36-54. 48) and BE at 3 meters 54. 18 (CI 95%, 53. 64-54. 72). There was a skew in the results for participants to achieve higher VA measurements.

Comparisons of mean VA results across 3m, 6m, and near distances showed a small mean difference of 1 or 2 letters. Although Pearson's correlation coefficients showed a strong level of statistical correlation (0. 84 p= 0. 01) the regression analysis determined that there was a weak relationship between the distances (3m, 6m, N).

Enmetropic and Myopic subjects show the lowest letter discrepancy at all testing distances whereas hypermetropes obtained the best mean VA at 6m then at near. Participants with presbyopia obtained a lower mean across all distances tested regardless of the refractive error they had as show in Figure 2. 0.

Figure 3. 0

A trend that was found that there is a decrease in the VA measurements found with increasing age independent of distance, with a steeper drop in the near visual acuity around the age of 40. Those in the age bracket of 60 and over had a lower mean VA at 3 meters and 6meters compared to the other age groups (mean RVA = 44. 62 p <0. 01, LVA = 45. 19 p <0. 01).

Participants under the age of 10 obtained higher NVA and 3m results than at 6 metres, whereas those between the ages of 10-40 had best VA at 3 meters

and those over the age of 40 had higher VA measurements at 6 metres as show in Figure 4 below.

OCULAR STATUS

Participants with ocular pathologies were recorded, a total of 57 subjects reported as having conditions (12%). Conditions were broken down by RE and LE as show in table 3 below, pathologies were examined according to individual eyes as conditions may occur monocularly or binocularly, therefore the total amount of eyes was 950.

A large number of the reported conditions were age related disease processes. Cataracts were the most common occurrence, being present in 34 eyes in total (3. 58%) followed by glaucoma found in 17 eyes (1. 79%)

Table 3: Breakdown of Ocular Conditions by Age

When ocular pathology conditions were ran against the differences in VA at various distances, there was no significant relationship found, however it was noticed that where there was a change of 2 letters or less between the distances of 6m and 3m there was usually the presence of a cataract. This situation was not found with any other ocular conditions

As there were no significant differences found for VA measured at different distances, it can be concluded that measurements are comparable at 3m and 6m. It was also found that refractive error or ocular pathology had little impact upon mean VA at various distances.

DISCUSSION

The general findings of our study showing a minimal change in visual acuity measurements with changes in the testing distance, is in agreement with the current literature. More importantly this study unlike previous work32 has identified the variations of VA at distances that are clinically relevant. Earlier studies have claimed that discrepancies between visual acuity measures only transpire once the testing distance is brought closer than 2 meters31. This is consistent with our findings as we found minimal differences between the VA at 6m and 3m.

There was a consistent finding of higher mean VA scores for the left eye than the right eye at all three distances; this could be attributed to the learning curve or subconscious memorisation of the chart, there was a protocol put in place (every 2nd subject to be tested with left eye first) to remove this potential confounder however due to the number of examiners there remains the question as to how often this was enforced.

One of the facets of our study was to investigate whether refractive error had any impact on visual acuity measured at different distances but we were not able to find any association between these variables. However as refractive error was classified according to glasses prescription and not any type of refraction, the validity of results can be questioned. Those presenting as enmetropes may have a mild form of refractive error especially for hypermetropes who can overcome blurring through accommodation.

Theoretically hypermetropes are meant to perform visual acuity assessments better at distances than at near as their accommodation allows

for them to increase the power of their lens22. This is in agreement with the results of our hyperopes between the distances of 6 m and 3 m. However the hypermetropes surprisingly had a higher mean NVA than the results obtained for 3m. Unfortunately this result cannot be explained however it may be attributed to the limitations of the study.

There was a relationship noted between presbyopia and reduced VA at all testing distances, this could be purely because the gradual loss of accommodation ability will cause blurriness at any distance, including at 6m. There could also be a compounding effect, as those that presented with cataracts were over the age of 40 where other age related pathology could also start affecting the eye.

We have found that there is a decrease in the VA results at near for all age groups excluding below 10 year olds. This reason why this phenomenon occurs is still unexplained. However we know that the visual system in young children take up to on average the age of 5 to mature, and even then to not achieve the same VA results at distance (6m) as adults30, it is also recommended by the to test children at a closer distance to get better results for psychological reasons18.

Another factor that may affect the results of NVA is the testing order and patient fatigue after prolonged testing, clinically patients will be requested to read the smallest line possible in each eye before moving onto NVA, however in this particular study, it is prolonged testing of both eyes at different distances before investigating NVA. This issue significantly impacts on the reliability on finding consistently reduced near visual acuity.

It must also be noted that NVA charts were individually printed by the examiner; this creates a disparity between equipment as the different printer and paper quality are most likely different which would impact on the contrast and detail of the reduced Snellen chart. Also, although the maximum score was 33 letters, even the electronic copy of the reduced Snellen could not be seen clearly therefore results may be expected to be lower.

Confidence in the results depends on validity of the study therefore the limitations need to be addressed and interpretations of any findings needs to be approached with caution. The subjects used for our study was a sample of convenience it would not be a true representation of the population. Subjects were selected from a variety of locations, family, community groups and clinics and may have been chosen for their ability to provide specific information such as glasses prescription or they presented with an ocular condition, as such results may have been skewed as participants obtained from clinics have a higher tendency to present with ocular pathologies. This sampling bias would be a threat to the internal validity of the study.

Other issues stemming from having a sample of convenience is that there was not an even distribution of age. Each data collected was responsible for collecting 5 participants greater than 40 and 5 participants under 40 including 2 subjects under the age of 13 to generate a stratified sample; however this was not reached by all examiners. There was an over representation of the 20-29 year olds and under representation of 30-30 year olds, this meant that there were not enough subjects to be completely

confident in the trends we found regarding decreasing VA measurements with age.

Our sample size of 475 was not large enough to give the statistical power needed to substantiate our findings, even more so when the analysis was run against smaller subgroups based on age and refractive error. With a smaller number of participants we were unable to have an even distribution of refractive error, and within those classifications (myopia, hyperopia) there was not a wide range of SE to detect whether the amount of refraction could impact on the VA obtained at different testing distances. There were also a low percentage of the subjects that had an ocular condition; this does not allow for detailed analysis on whether ocular pathology truly had an effect on VA.

Reliability of the results depends on the internal validity of the study; as there were a total of 48 examiners, the methodology of data collection needed to be uniform to reduce inter observer variation. Strict procedural instructions were given for the examination technique in obtaining VA results however monitoring of testing environment was not specific. Examination locations varied from clinician rooms to outdoors. It has been established that room illumination and contrast will impact on the VA measurements obtained. Examinations that were conducted outside would have had a high variance of illumination dependent on the weather and time of day.

A few of data fields were reliant upon patient reporting, such as refraction and ocular pathology, a number of these were accessible through medical files however a majority of participants were not selected from clinics and so

the accuracy of self-reporting is unreliable. As one of the major focuses of our study was refractive error, greater care should be taken in obtaining this information. Measurement by vertometry is more reliable that estimating the prescription of the lens and whether possible cycloplegic refraction to prove true enmetropia.

The classifications of our ocular pathologies may also have impacted on our results, for example pseudophakic patients that previously had cataracts were categorised as having cataracts at the time of examination.

To confirm the findings of our study, further research that utilises a randomised sampling method in a controlled environment, with a larger sample size needs to be conducted.

CONCLUSION

Our findings from this study show that testing distance does not impact on the visual acuity measurements obtained as we had consistent results for 3 and 6 m. Ocular pathologies and refractive error were not found to have an effect on VA however this needs to be investigated further. A study of further interest may be to investigate whether the power of the refractive error influences the impact of testing distance on visual acuity for example a high myope compared with a low myope.

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