Parameters Affecting Performance of Visual Acuity Tests: A Statistical Analysis

ME 794 Project Report

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***Abstract*—Visual acuity tests are commonly used to measure an individual's ability to recognize fine details. In particular, optometrists and ophthalmologists employ standardized visual acuity tests such as Snellen's distance vision test and near vision cards for prescription of lens powers for patients. In this project, we investigate the parameters affecting the performance of visual acuity tests among college students.**

In particular, we design and conduct an experiment to determine whether an individual's biological sex has an impact on their visual acuity performance. Following the experiment, we make use of standard statistical analysis techniques such as two-sample T tests and analysis of variance (ANOVA) tests in order to validate our initial hypotheses. The results of this analysis can help improve reliability of visual acuity tests as well as develop any targeted interventions in case there are significant performance differences observed in the tests.

I. Introduction

Visual acuity tests are commonly used in order to measure an individual's ability to perceive details of objects at a given distance. There are standardized tests to measure visual acuity for distance vision as well as near vision. One of our main motivations to conduct a study on this topic stems from our daily observations of college students. Vision-related problems are an increasingly common occurrence among teenagers, a common example being students not being able to read lecture slides/notes at a distance.

Fig 1: Near Vision Card

Some of the most common visual acuity tests include Snellen's test, the Tumbling E test and Lea symbols for testing distance vision, as well as near vision cards and contrast sensitivity tests for near vision testing.

Near vision cards, as demonstrated in the figure alongside, are used to test for near vision. The test is conducted at a distance of about 14 inches and requires the patient to read out lines that decrease in size as they proceed. A person who is able to read text of size N5 is considered to have "normal" vision. Contrast sensitivity tests make use of letters and symbols embedded in a circular grid of dots belonging to the same family of colours. The patient is required to be able to distinguish the letter or symbol using the slight differences in contrast between neighbouring dots. We do not go into much depth regarding near vision testing in this project, given that our target group of individuals contains a fairly young population.

Fig 2: Snellen Chart

For distance vision testing, the Snellen chart is by far the most popular technique. It involves a sequence of rows of randomly determined letters which decrease in size from top to bottom. Patients are assigned a visual acuity score based on the final line they are able to read with reasonable accuracy. The visual acuity score is represented as a fraction, with the numerator representing the distance of conducting the test (typically fixed at 20 feet) and the denominator representing the distance at which a person with "normal" vision would be able to read the line. For example, a person assigned a score of 20/40 has poor vision since they are able to distinguish a particular line at a distance of 20 feet, whereas a person with normal vision is able to read it from a farther distance of 40 feet.

Some other testing methods follow a similar principle but differ in design. The Tumbling E test involves a chart with rows containing only the letter E, assigned a random direction (up, down, left, right), decreasing in size from top to bottom. The Lea symbols test also uses a similar pattern, except the patient is required to distinguish the shape of the symbol - this testing method is commonly used for infants who have not developed a full understanding of the alphabet yet.

II. The Problem

When considering the impact of various parameters on the performance of visual acuity tests, we must first define some control parameters. Some of the factors that are typically controlled in a visual acuity testing setup are:

- Size & font of letters or symbols - This is typically fixed for standard charts used for visual acuity testing.
- Colour & contrast of letters or symbols - In order to remain as unbiased to colour blindness effects as possible, most charts are designed to be grayscale. One exception is the contrast sensitivity test which involves coloured images for distinguishing contrast changes within the same family of colours.
- Distance at which the test is administered - This is again determined by the type of testing conducted.
- Type of testing- This is dependant on the eyesight problems by the patient, following which a decision to conduct either near or distance vision testing is made.
- Lighting conditions - Most tests are carried out in a well-lit space and designed to eliminate any effects of shadows being cast on the testing equipment.

Parameters which, on the other hand, can typically not be controlled are the age and gender of the patient being tested. Also, their existing medical conditions are difficult to account for during vision testing as well. In our experimental setup, we aim to test the effect of gender by virtually treating the age as a control variable, given that our target audience is between a relatively small age gap of 19 to 22 years.

During our preliminary research of this topic, several literature pointed to there being no discernable difference between vision for males and females of similar age groups, while some literature displayed evidence for the opposite point of view and argued that there was reason to believe that males, on average, had slightly better vision than females of the same age demographic. Intrigued by these contrasting observations, we tried to formulate our own experiment, trying to limit the impact of factors other than gender to a minimum.

III. Design of Experiment

Based on the PowerPoint presentation slide you provided, here is a summary of the experiment that can be included in a report:

The experiment aimed to investigate whether gender has an effect on visual acuity among students. To control for other variables that could influence the results, the experiment included the following control variables:

- Test subjects: 12 male and 12 female candidates were selected each week for 3 weeks. The participants from the first week were tested again in the fourth week to implement blocking of effects of weather and lighting conditions.
- Distance: The distance from the Snellen chart was fixed at 25 feet.
- Time: The experiment was conducted during lunchtime, between 12:30 - 2 pm.
- Visual aids: Only students who did not rely on visual aids (contact lenses, spectacles) were chosen as test subjects.
- Snellen charts: Three different Snellen charts with the same fonts and sizes were used to repeat the experiment three times and average the readings.
- Age: Age was taken as a control variable since participants were between 3rd and 5th year students of IITB.

The equipment used in the experiment included:

- Snellen charts: Three versions of the standard chart used for eye testing.
- Measuring tape: The distance was measured using a tape with a least count of 1 foot.

The experimental procedure involved:

- The test subjects were asked to read the letters on the Snellen chart slowly and one at a time.
- If a letter was wrongly identified, the test subject was asked to move one foot closer to the chart until they could read all the letters in the 20/20 line.
- The distance from which the letters in the 20/20 line could be correctly identified was noted down.
- This process was repeated twice for the other two Snellen charts.
- The three readings were averaged, and the result was recorded in the observations table.

Overall, the experiment was designed to minimize the impact of confounding variables and obtain accurate measurements of visual acuity among male and female students. The data collected can be used to test whether there is a statistically significant difference in visual acuity between male and female students.

IV. Observations

Observations for the first week of data for half of the participants are shown in Table 1. The columns indicate the gender of the participant, the distances measured for each of the three Snellen charts as described in the experimental design and the mean of these three distances.

V. Statistical Analysis

As mentioned in the sections before, the tests were conducted in such a manner that the same participants were tested

TABLE I
OBSERVATIONS FOR WEEK 1

Gender	D_1	D_2	D_3	Mean
Male	20	22	20	20.67
Male	18	19	18	18.33
Male	18	18	16	17.33
Male	19	16	18	17.67
Male	20	18	21	19.67
Male	18	17	19	18
Female	22	23	22	22.33
Female	19	20	19	19.67
Female	16	16	15	15.67
Female	17	20	19	18.67
Female	24	23	21	22.67
Female	21	19	21	20.33

in Week 1 and 4. The reason for this design choice is to implement blocking in order to minimize any error due to weather and/or lighting conditions between weeks. This is, of course, not a completely foolproof method of testing, but could counteract variational noise to a certain extent as well as increase the confidence in the obtained results. The results of the 2-factor analysis of variance (ANOVA) test performed on the collected data for weeks 1 and 4 is shown in Table 2 as follows:

TABLE II
ANOVA TABLE

Source of Variation	Sum of Squares	DoF	Mean Square	F_0
Treatments	0.33	1	0.33	0.09
Blocks	5.33	1	5.33	1.44
Error	166.32	45	3.69	
Total	0.33	1		

Since the calculated value of the F-statistic (1.443) is lesser than its critical value (4.057) for a confidence bound of $\alpha = 0.05$ and degrees of freedom of 1 & 45 respectively, we fail to reject the null hypothesis. Hence, we conclude that the collected data does not show any significant variation across weeks and that our experimental design is reasonably robust to variational noise in parameters.

A second method of analysis was employed for testing the second pair of hypotheses. Since there are only two gender categories, we use the two-sample T test to analyse the results. Using a confidence bound of $\alpha 0.05$, we get the following results:

- Mean of distance for males $\mu_m = 20.340$ ft
- Mean of distance for females $\mu_f = 20.333$ ft
- Standard deviation of distance for males $S_m = 1.852$ ft
- Standard deviation of distance for males $S_f = 1.656$ ft
- Pooled standard deviation $S_p = 20.340$ ft

Using these results, the calculated value of the t-statistic is around 0.0193. This is again lower compared to the critical value of the t-statistic (1.986) for the required degree of freedom of 94, which again indicates that there is not enough evidence for rejecting the null hypothesis. Hence, we conclude that that the gender of the patient does not significantly affect their performance in visual acuity tests.

VI. CONCLUSIONS

In conclusion, our experiment aimed to investigate whether gender has an impact on visual acuity performance among students at IITB. Through our study, we found that there is no significant difference in visual acuity performance between male and female students. The mean distances for males and females in identifying the letters were almost the same, and the standard deviation was also similar. The statistical analysis using a two-sample T-test showed that the difference between the means of the two groups is not statistically significant, thus leading us to reject the alternate hypothesis that gender has an impact on visual acuity performance.
However, our study is not without limitations. The sample size was limited, and control variables may not be sufficient to account for all factors that could affect visual acuity. Moreover, possible effects of learning and human error could have impacted the accuracy of the measurements. Future studies should aim to address these limitations to achieve more robust results.
In summary, our study contributes to the existing body of research on visual acuity performance and gender differences. The results of this study can be useful in improving diagnostic accuracy and reliability of vision screening and developing targeted interventions for different patient populations.

VII. LIMITATIONS OF THE EXPERIMENT

Tt is important to acknowledge the limitations of the methodology and data used. In this section, we will explore some of the key limitations and their potential impact on the results.

- Limited sample size - The sample size of 12 male and 12 female participants each week for three weeks may not be representative of the entire population of students at IITB, which could impact the generalizability of the results. A larger sample size and more diverse population would provide more reliable results.
- Control variables may not be sufficient - While the study controls for some variables such as time of conducting the experiment, there may be other factors that could affect visual acuity, such as the health status of the participants or the weather conditions. For example, the experiment was conducted in a well-lit area, but lighting conditions can vary significantly across different settings. Also, the females were tested in a different setting from males in different hostels, which may have led to differences in ambient conditions of the experiment. In future studies, these factors should be taken into account to improve the accuracy and reliability of the results.
- Possible effect of learning - As participants completed the test more than once, they could potentially learn how to perform better on the test with each trial, which could

affect the accuracy of the results. To minimize this effect, future studies could use a larger pool of participants to reduce the number of repeated trials for each individual.

- Room for human error - The accuracy of the measurements may be impacted by human error in conducting the experiment, such as improper measurement of the distance or recording incorrect responses. To reduce the impact of human error, future studies could use more automated equipment and procedures to increase accuracy and consistency.
- Lack of consideration of medical conditions - While the study controls for some medical conditions such as refractive errors, cataracts, and glaucoma, other medical conditions that affect visual acuity were not taken into consideration. Future studies could incorporate more comprehensive medical assessments to account for a wider range of medical conditions that could impact visual acuity.

VIII. References & Links

[1] Visual Acuity Test: Types, Procedure & Interpreting Results (clevelandclinic.org)

[2] Snellen chart - Wikipedia

[3] Sex-related differences in vision are heterogeneous - PMC (nih.gov)

[4] Gender differences in visual perception (researchgate.net)

[5] Gender and age differences in visual perception of pattern randomness (spp-j.com)

[6] Gender and environmental influences on visual acuity in Owerri, Nigeria

The entire set of observations made during the experiment can be found in the spreadsheet linked `here`.