Visual Acuity Assessment: A Comprehensive Survey of Methods

Maryam Ansari[1], Zafar Shaikh[2], Abdullah Ansari[3],Ansari Raheen Bano[4], Nafisa Mapari[5]

Students, Department of Computer Engineering[1,2,3,4]

Assistant Professor, Department of Computer Engineering[5]

M. H. Saboo Siddik College of Engineering, Mumbai, Maharashtra, India

Abstract: *This review paper focuses on the various methods and tools available for measuring visual acuity, a crucial aspect of visual function that is used to diagnose and monitor a wide range of ocular disorders. The paper provides an overview of the basic principles of visual acuity measurement and examines the most used techniques, including Snellen charts, the Rossano-Weiss test electronic Measurement of Visual Acuity (eMOVA)test, and paper-based tests (PBVA). The strengths and weaknesses of each method are discussed, along with the factors that can affect the accuracy and reliability of visual acuity measurements. The paper also considers recent developments in visual acuity testing, such as the use of Natural Language Processing, Machine Learning along with smartphone apps, and explores their potential benefits and limitations. As a whole, this review paper provides a comprehensive and up-to-date analysis of the different approaches to measuring visual acuity and highlights the importance of careful consideration of the choice of the test method in clinical practice.*

Keywords: Acuity, Snellen Chart, eMOVA, Rossano-Weiss, vision

I. INTRODUCTION

Visual acuity is a crucial measure of the health of our eyes and the efficiency of our visual system. It refers to the ability to see fine details clearly and distinguish between objects at different distances. The Snellen chart has been the most used method for measuring visual acuity for over a century. However, it has its limitations, and several factors can influence the accuracy of the results, such as lighting conditions, chart distance, and the choice of test chart or symbols.

Recent technological advancements have led to the development of novel methods for measuring visual acuity that address some of these limitations. Some of these methods include computer-based visual acuity testing, which can be conducted remotely, and mobile applications that can measure visual acuity with high accuracy. However, these new methods also bring their challenges, such as the need for standardized protocols and calibration procedures. Nevertheless, the potential benefits of these new methods are significant, and they could improve the accuracy and efficiency of visual acuity testing, particularly in remote or challenging settings.

Accurate measurement of visual acuity is essential in diagnosing and monitoring visual disorders, particularly those affecting the retina, optic nerve, or visual cortex. These disorders can lead to severe vision loss, which can negatively impact the quality of life of affected individuals. Therefore, improving the accuracy and efficiency of visual acuity testing is critical in detecting these conditions early and facilitating prompt intervention. In addition, measuring visual acuity can also be useful in non-medical settings, such as in schools, where it can aid in identifying children with vision problems and ensure they receive appropriate support.

The remainder of the paper is organized in the following manner: Section II provides a summary of various studies conducted on the measurement of visual acuity. Section III examines the gaps in the research and proposes a system to address them. Lastly, the paper concludes in the last Section IV.

II. REVIEW OF MEASURING VISUAL ACUITY

Nayan Sanjay Bhatia et al. worked on a model that includes Snellen's Chart; they tested it using two distinct methods, one of which used a periscope and Snellen's chart and provided an accuracy of 98%, while the other did not [1].

Christopher J. Brady et al. offered a method for creating and evaluating a visual acuity test for smartphones without the need to be familiar with standard English symbols or letters [2]. The Early Therapy Diabetic Retinopathy Study

(ETDRS) LogMAR chart and Snellen acuity (clinical normal) charts were used in a four-month validation study to compare the results from the peek acuity app for cell phones. 300 people aged 55 and older were enrolled in the study. The 95% CI limit for test-retest variability for the smartphone acuity data was 0.029 LogMAR. The mean discrepancies between the smartphone-based test, the ETDRS chart, the smartphone-based test, and the Snellen acuity data were 0.07 (95% CI, 0.05-0.09) and 0.08 (95% CI, 0.06-0.10) LogMAR, respectively. The Peek Acuity and ETDRS charts' agreement was higher than the Snellen and ETDRS charts' agreement (95% CI, 0.05-0.10; P =.08). The results of the study demonstrated that the Peek Acuity smartphone test can validate visual acuity with accuracy and repeatability that is consistent with data on the test-retest variability of acuities assessed using 5-letter-per-line retro illuminated LogMAR charts.

Akash Agarwal et.al. introduced an Android application for measuring visual acuity using the standard Snellen chart [3]. The screen-to-face distance is calculated using the front camera and the flickering space between the two eyes. This separation was noted in order to resize and alter the typefaces appropriately. With the aid of font activity, the same is utilized as an input to modify the Snellen chart's letter size, which changes dynamically, that is, shrinks after every three words. According to the distance between the screen and the face, each row is resized. Every time an alphabet is displayed to the user, he must read the letter whose accuracy is determined by Android's speech-to-text conversion. Until the user is unable to correctly identify two letters from a row, this process is repeated. If this occurs, the activity is halted, and the user is shown the visual acuity for that row. Every row on the Snellen Chart has a visual acuity (VA) value attached to it, and it is based on that value that one can establish whether the user has normal vision. Before the visual acuity test, a questionnaire was also administered as part of the study. Many scenarios involving eye patients are examined before the questionnaire is created. A reasoner is used to analyze the database, which was created using OWL and RDF, and predict potential faults based on the responses. If the user is found to have any flaws based on his or her answers to the questionnaire, the program will use GPS to show the user the closest eye care facility, ophthalmologist, or hospital that is within 5 miles of where they are now located.

Soham Mehta et.al. created Ocufy, a mobile eye-testing application [4]. They employ a method that includes face detection and calculates the screen-to-face distance, or the space between the user's eyes and the mobile screen. The user is then promoted with a quiz after the distance metric has been taken care of, where several characters, also known as optotypes, of various sizes are provided. The user must then consecutively close each eye to receive a score for each eye. The number of characters that the user correctly identified is used to determine the quiz's score. The result is calculated using the Snellen Chart, which is the industry-standard method for determining visual acuity. The study's prediction of the right outcome was 85% accurate.

Miki Uchino et.al. stuck with the Paper-based visualacuity (PBVA) method [5]. The paper-based method included a questionnaire that was to be filled out by the subjects/patients. The subjects were approximately 300 Japanese patients, mostly men who were asked to self-rate their visual acuity. Maximum patients were healthy apart from 32 subjects who had an ocular disease and 25 who had a systemic disease. The mean PBVA score was 2.9±0.6, and the mean logMAR initial VA was 0.01±0.17[5]. The final results stated 88 patients with good vision, 131 with average vision, and 82 with low/poor vision.

Noemie Stoll et.al. examined the participants over 2 tests i.e., the electronic Measurement of Visual Acuity (eMOVA) test and the Rossano-Weiss test [6]. Participants consisted of 100 children of the age group ranging from 3 to 8 who were visiting a pediatrician for an eye examination. As per the reports, the mean difference between both tests was -0.06 logMAR or 0.3/10 for the right eye and -0.01 logMAR or 0/10 for the left eye[6].

Neal A Patel et.al.presented a technique based on dynamic distance measurement from the human corneal limbus for eye examination [7]. The mobile eye exam suite allows patients to evaluate their visual acuity swiftly and correctly, enabling the system to monitor chronic retinal illnesses. The appropriate visual acuity is calculated by increasing the LogMAR (logarithm of the minimum angle of resolution) values starting at a reference LogMAR value of 0 (the Snellen equivalent of 20/20) and moving forward in increments of 0.1. The two most important procedures in this investigation are face and corneal detection. The accuracy and generalizability of the algorithm were evaluated using 200 static photos, 25 images of men and women from four distinct ethnic groups from the Chicago Face Database (CFD), and live image streams from a test subject. Although the overall average absolute error across the range of 12 to 16 inches is 0.987%, attesting to the high accuracy of the algorithm for distance determination in real-time.

In order to determine a person's visual acuity, C Perera et al. recommended a study of many applications available on the Apple Appstore. [8]. This inquiry was divided into two parts. First, a review of the iPhone Snellen chart apps that were already out there had been done. Second, a comparison between the iSVA (Snellen visual acuity on a smartphone) and the 6SVA (Standard Snellen Chart) was done. Checking that each application has a Snellen chart with precisely defined test distances was the first step. Only one application from a publisher was taken into consideration for the evaluation if all the applications were identical but had different names. Each application's name, publisher, rating, year of publication, and price were documented before it was downloaded. The letter sizes of each application were then measured. Next, using the idea of trigonometry, optotype height was determined for a specific Snellen acuity line. The accuracy for each line was calculated by comparing the anticipated optotype height to the actual letter height. The mistakes for each line were averaged to determine the program's overall imprecision. For the investigation, a total of 88 patients were drawn from the inpatient wards of a university teaching hospital in Melbourne, Australia. According to the survey, various apps had error rates ranging from 4.40 to 39.90%. With an average line precision of 4.4%, the Eye Test by Bokan Technologies (2009) was the most precise program among them. Two apps, with an average line error of more than 30%, were also the most inaccurate.

Alberto De Bortoli et al. created a program called PlayWithEyes that tests children's eyesight through a game that uses Various symbols and images from well-known cartoons to catch their attention [9]. The application seeks to assess color blindness in addition to visual acuity. It has a client-server design, where students act as clients to play games that act as pre-configured tests while teachers administer the server to configure tests. Kindergarteners between the ages of 3 and 6 have tested the method. In the future, 200 kids and 18 teachers will participate in the second phase of testing for the system. Unfortunately, neither the system's effectiveness nor the analysis of the test findings was mentioned.

Ai Hong Chen et.al. set side by side 3 different letter charts under 2 varied ambient room illuminations [10].The experiment consisted of students between the ages 19 to 23 of which 7 were males and 23 were females. Table I summarizes the methods, the dataset used, results, and research gaps along with the drawbacks.

Table I: Summary of studies performed

Work Cited	Study	Method used	Dataset	Results	Drawbacks and Research gaps
[1]	Nayan Sanjay Bhatia et.al.	Snellen Chart + Periscope	No dataset used	Accuracy without periscope: 100% Accuracy with periscope: 98%	Any deposition of moisture and dust on the mirror will reduce the reflection to nil.
[2]	Christopher J. Brady et.al.	-	No dataset used	The smartphone acuity test had a test-retest variability 95% CI of ±0.029 log MAR. Mean differences were 0.07 log MAR (95% CI, 0.05-0.09) for smartphone vs. ETDRS chart and 0.08 logMAR (95% CI, 0.06-0.10) for smartphone vs. Snellen acuity data.	-
[3]	Akash Agarwal et.al.	Screen-to-face distance calculation, Use of Snellen chart, Speech-to-text conversion	No dataset used	-	The screen-to-face distance can change if the user moves the device. The size of the letters is thus fixed for a set distance. The application will be

					more accurate if the test is taken in a closed room.
[4]	Soham Mehta et.al.	Face detection Calculation of distance between eyes and phone +Snellen Chart	No dataset used	Accuracy of correct result prediction: 85%	Users wearing spectacles are required to conduct 4 time-consuming tests. No eye clinic suggestions were provided.
[5]	Miki Uchino et.al.	Paper-based visual acuity (PBVA) i.e., with the help of a questionnaire	301 young and middle-aged, mostly male, Japanese subjects were asked to self-rate their visual acuity.	10.6% of subjects had an ocular disease, and 8.3% had a systemic disease. The mean PBVA score was 2.9±0.6, and the mean logMAR initial VA was 0.01±0.17. 29.3% reported good vision, 43.5% reported normal vision, and 27.2% reported poor vision.	The questionnaire lacked specificity and had uncertain accuracy. Potential male selection bias in subjects. Future study is needed for daily vision fluctuations. Low PBVA specificity can lead to high false positives and requires careful interpretation. Future research should focus on sex-matched PBVA for remote VA measurement.
[6]	Noemie Stoll et.al.	Visual acuity was assessed on participants using both the electronic Measurement of Visual Acuity (eMOVA) test and a Standard test (Rossano-Weiss test)	A cohort of 100 children aged 3 to 8 attending the ophthalmic-pediatric for eye examination between September 2016 and June 2017 was included in the study	eMOVA test had a mean difference of -0.06 logMAR (RE) and -0.01 logMAR (LE) for near visual acuity. Wilcoxon test showed a statistically significant advantage in eMOVA. eMOVA is a reliable and highly portable tool for routine hospital exams, suitable for assessing children's near visual acuity.	The study shows the lack of accuracy between the two tests but does not talk about the test whose measurements are closest to reality. The duration of the eMOVA test was longer than the reference test.
[7]	Neal A Patel et.al.	Digital image processing+ randomized circle detection+ Dynamic distance determination from the human corneal limbus detection algorithm+LogMar	Chicago Face Database (CFD) Standardized facial photographs of males and females of four ethnicities between the ages of 17 to 65.	-	The minor variations between the actual corneal center and the predicted corneal center had an impact on the accuracy of distance determination,

		algorithm			
[8]	C Perera et.al.	6-m Snellen visual acuity (6SVA) chart + a visual acuity chart application 'Snellen' DrBloggs Ltd running on an Apple. iPhone 4 Apple Inc., 2011	88 patients were recruited to test their visual acuity using different applications to test visual acuity	Errors rates of different applications ranging from 4.40 to 39.90%. Eye Test by Bokan Technologies (2009) was the most accurate application. with an average line inaccuracy of 4.4% Two applications were found to be the most inaccurate with average line inaccuracies greater than 30%	-
[9]	A. Bortoli et.al.	A game that uses Various symbols and images from well-known cartoons to assess color blindness in addition to visual acuity.	Kindergarteners between the ages of 3 and 6	-	No analysis has been done
[10]	Ai Hong Chen et.al.	Comparison of visual acuity estimates using three different letter charts under two ambient room illuminations.	Students aged between 19 and 23 years old (7 males, 23 females)	Visual acuity estimates showed no statistically significant difference when measured with the room light on and with the room light off. Visual acuity estimates were significantly different between the Snellen projected chart (PC) and between SnellenWall mounted (WM).	To produce consistent visual acuity estimates, calibration of the instruments and room arrangement is necessary when using PC and WM screens in optometric clinical procedures. Failure to do so can lead to over- or under-estimation of visual acuity.

III. RESEARCH GAPS AND PROPOSED SYSTEM

3.1 Research Gaps

The system discussed in the earlier section proved to be fruitful in their respective requirements. However, there are research gaps that we discuss in this section.

The first study which used Snellen Chart+Periscope highlights a limitation of a mirror-based technology due to the deposition of moisture and dust, which can cause the elimination of reflection. In the study of Akash Agarwal et.al., the effectiveness of a testing application is compromised by the presence of noise, leading to inaccurate results [3]. However, there were no recommendations for eye clinics, and individuals with eyeglasses had to complete four time-consuming exams.

One of the studies emphasizes the absence of questions related to near or far vision, a potential bias towards male subjects, the lack of specificity in the Paper-based visual acuity (PBVA) test, and limitations in terms of the subjects' vision quality. Another study does not indicate which test measurements are closest to reality, although the electronic Measurement of Visual Acuity (eMOVA) test was preferred by children and parents. Another study emphasizes the importance of accurately determining the distance between the corneal center and the observer, which can impact the accuracy of distance determination.

The paper by Ai Hong Chen et.al. suggests that Snellen's projected chart (PC) and Wall mounted (WM) screens can generate more precise estimates of visual acuity in optometric clinical procedures with careful calibration of instruments and room arrangement [10]. Although the study highlights several gaps, it also emphasizes the need for further research to improve the accuracy and effectiveness of vision testing technologies.

3.2 Proposed System

The system would consist of several modules that work together to provide an easy-to-use visual acuity test.The first module would be a calibration step that determines the user's screen-to-face distance. This step would involve capturing a real-time video of the user holding their device upright and detecting the user's face to calculate their pupillary distance. This information can be used to calculate the distance between the user's eyes and the screen, which is necessary to display the Snellen Chart in the next module.

The second module would display letters of the Snellen Chart one by one and row-by-row. The size of the letters would be determined by the screen-to-face distance calculated in the previous module. The user would read each letter out loud, and the system would use speech-to-text conversion to compare the user's response with the displayed letter. If the user reads the letter correctly, the next row of the chart would be displayed. Otherwise, the test would stop, and the corresponding score would be recorded

The third module would be speech-to-text conversion, which converts the user's speech input into text. The system would compare the converted text with the displayed letter and decide based on the identification of the letter. Finally, the visual acuity score would be calculated based on the user's correct identification of the letters from the Snellen Chart. The score would then be displayed as the result of the visual acuity test.

Overall, this system would provide a user-friendly way to test visual acuity, which could be used in a variety of settings, such as optometry clinics or telemedicine consultations. It could potentially save time and resources, as it would not require the presence of a healthcare professional to administer the test.

IV. CONCLUSION

This review paper emphasizes the importance of accurate and reliable measurement of visual acuity in clinical ophthalmology and visual science research. The paper provides a comprehensive analysis of various techniques available for measuring visual acuity, including their strengths, weaknesses, and potential applications in clinical practice. It highlights the fact that no single method is suitable for all situations and that the choice of testing method requires careful consideration of factors such as lighting conditions, chart distance, symbol choice, patient's age, cognitive ability, and specific visual needs. The paper aims to inform clinicians and researchers about the latest developments in visual acuity testing, which will lead to informed decision-making and contribute to the advancement of clinical practice and visual science research.

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