iVRead: INTERACTIVE VIRTUAL REALITY FOR EARLY DETECTION OF AMBLYOPIA FOR KINDERGARTEN PUPILS

A Project Study Presented to the Faculty of

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In Partial Fulfilment of the Course Requirements for the Degree of

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Submitted by:

Aporado, Jonalaine P.

Ciria, Cloie Jed Allen L.

Custodio, Paul Vincent D.

Gallego, Ma. Daniella M.

Mangaliman, John Rey R.

Marcelino, Jonathan Jr O.

Adviser:

Engr. Nilo M. Arago

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APPROVAL SHEET

This project study entitled "**iVRead: Interactive Virtual Reality for Early Detection of Amblyopia for Kindergarten Pupils**", has been prepared and submitted by the following proponents:

Aporado, Jonalaine P.	Gallego, Ma. Daniella M.
Ciria, Cloie Jed Allen L.	Mangaliman, John Rey R.
Custodio, Paul Vincent D.	Marcelino, Jonathan Jr O.

In partial fulfillment of the requirements for the degree of **Bachelor of Science in Electronics Engineering** is hereby recommended for approval.

ENGR. NILO M. ARAGO
Project Adviser

ENGR. JAY FEL C. QUIJANO
Panel Member

ENGR. EDMON O. FERNANDEZ
Panel Member

ENGR. VILLAMOR M. AMON
Panel Member

ENGR. TIMOTHY M. AMADO
Panel Member

Accepted and approved in partial fulfillment of the course requirements for the degree of **Bachelor of Science in Electronics Engineering.**

ENGR. TIMOTHY M. AMADO
Head, ECE Department

ENGR. NILO M. ARAGO
Dean, College of Engineering

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ABSTRACT

Vision screening can identify children with amblyopia so that treatment can be initiated before vision loss becomes permanent. The National Vision Screening Program aims to conduct vision screening in the country by training teachers or other school personnel in measuring visual acuity among kindergarten pupils. Visual acuity measurement can be supplemented by tests that measure refraction and eye alignment in order to detect amblyopia and identify its cause. In this study, we evaluate the testability and accuracy of a VR device (VRD) that can measure refraction, visual acuity, and alignment. The visual acuity is done using HOTV chart displayed in a VR environment where the patient's response is recorded through speech recognition. The light reflex test utilizes CCLRR (Central Corneal Light Reflex Ratio) obtained through image processing, specifically using the Hough and blob algorithm. The refraction is implemented using Shack-Hartmann wavefront sensing, wherein the raw image from the sensor undergoes Zernike polynomials, and fast Fourier transform to extract the lower aberrations of the eyes. The device is designed to operate by non-medical practitioners. It is controlled using an android application where the data obtained from the device can be uploaded to a cloud-based database in real-time, which can facilitate information retrieval for referral to an eye care practitioner or research. The visual acuity test is proven to be effective by analyzing the data gathered using the Wilcoxon signed-rank test as the median of the population of the paired differences is zero. Moreover, in the light reflex test and refraction, the paired samples t-test proved that the data from the device had no significant difference from that of the clinical data of patients.

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CHAPTER 1

INTRODUCTION

This chapter presents the background of the study, statement of the problem, objectives, significance, and the scope and delimitation of the study.

1.1 Background of the Study

Amblyopia is a unilateral or bilateral reduction in best-corrected vision in the absence of organic pathology. It arises if a treatable condition causes a decrease in the quality of vision during the critical period of visual development. These conditions are usually high refractive errors, asymmetric refractive errors between the two eyes, strabismus, or causes of obscuration of the visual axis such as cataracts or ptosis. Amblyopia is relatively easy to correct up to about eight years old [1]. Untreated amblyopia beyond this period may result in permanent vision loss, adversely affecting a child's development, learning, and quality of life.

Amblyopia meets the World Health Organization guidelines for a disease that benefits from screening because 1.) it is an important health problem for which there is an accepted treatment, 2.) it has a recognizable latent or early symptomatic stage, and 3.) a suitable test or examination is available to diagnose the condition before permanent vision loss occurs [2]. Vision screening performed at an early age and at regular intervals throughout childhood has been demonstrated to decrease the prevalence of amblyopia. In the Philippines, the National Vision Screening Act or Republic Act 11358, signed into law on July 31, 2019, targets vision screening for all kindergarten pupils aged 5-6 [3].

The National Vision Screening Act, led by the Department of Education in coordination with the Department of Health (DOH) and the Philippine Eye Research Institute (PERI), aims to conduct a simple vision screening test to be administered by trained teachers and health personnel. It also aims to develop a referral system to eye care practitioners, conduct continuing research on visual impairment, and establish a vision screening database for all kindergarten pupils. One of the provisions of the law is that DOH and PERI may recommend the adoption of new modes or methods of vision screening based on the latest trends and developments [4].

The examinations involved in vision screening depend on the age of the child. Most children aged 3 to 5 can complete vision acuity testing with optotypes. Instrument-based screening techniques, such as photoscreening and autorefraction, are useful for children ages 1 to 5 years [5]. The Technological University of the Philippines has recently developed a portable autorefraction device utilizing the Shack-Hartmann wavefront technology. This technology has been shown to yield refraction data that is comparable to subjective refraction and table-mounted autorefraction. They could also incorporate a visual acuity chart in the device using virtual reality. Data from the device can be uploaded to a cloud-based database, which can facilitate information retrieval for referral to an eye care practitioner or research.

The iVRead is a device that measures refraction and eye alignment and aids in testing for visual acuity. This study aims to determine the testability and accuracy of this portable, inexpensive, and simple-to-use vision screening device among Filipino children aged 5-6.

1.2 Statement of the Problem

Four (4) out of forty (40) pupils in a class have vision impairment nationwide; one may have amblyopia, and three of them may have refractive error [3]. Amblyopia is one of the leading causes of visual problems that usually leads to blindness. Research findings show that the condition can still be prevented if amblyopia can be detected early. Failure to diagnose and treat this condition will negatively affect the patient's visual system, including decreased visual acuity, binocular vision, and contrast sensitivity, thus hindering some of the patient's regular activities, education, and future career opportunities. The government implemented the RA 11358, or the "National Vision Screening Act," mandatory for kindergarten pupils to address this problem. One significant struggle of ophthalmologists and lay screeners in vision screening in children is their misbehavior. Younger patients are usually shy and uncooperative. Children are notorious for getting preoccupied easily, and they also have their natural need to move restlessly.

Moreover, traditional instruments and devices used for vision screening can be challenged due to several factors, most notably training, mobility, and cost. The researchers acknowledge the necessity for a portable device to increase the child's compliance and make the overall vision screening enjoyable and accurate that can be used by ophthalmologists and other trained personnel.

1.3 Objectives

1.3.1 General Objectives

The research aims to develop an Interactive Virtual Reality device to detect amblyopia among kindergartens.

1.3.2 Specific Objectives

1. To design and develop a device utilizing Virtual Reality technology that will perform visual acuity test, light reflex test, and refractive error detection.
2. To develop a 3D software animation, an android application for the system control panel, and a website that will display the vision screening results.
3. To develop algorithms for visual acuity test, light reflex test, and refractive error detection and an algorithm to determine the presence of amblyopia based on the three tests.
4. To test the device using comparative testing and evaluate the device using ISO/IEC 25010 standard.

1.4 Significance of the Study

Portable devices, smartphone applications, and attachments have been increasingly utilized for eye tests. One of the reasons is that it can bring the technology to the patient instead of having the patient go to clinics or centers. In a country like the Philippines, communities outside major urban cities have limited access to eye care because of a lack of transportation, facilities, and eye care professionals. Portable technology can bridge this gap.

The iVRead device was constructed using inexpensive materials and technology. It was intended to complement the vision screening kit provided by PERI in order to improve the detection of amblyopia and its risk factors among kindergarten children. If the device is proven accurate, it would be beneficial to ophthalmologists, lay screeners, nurses, and other personnel in educational, public health, community, or primary health care settings. This study will benefit the participants who will be screened because it will be able to identify children who need a referral to eye care specialists for treatment.

1.5 Scope and Limitations

This study aims to design and develop a device that utilizes head-mounted virtual reality technology that will accurately measure refraction, eye alignment, and visual acuity to detect amblyopia risk factors in children 5–6-year-old.

The limitations of visual acuity test are 1.) HOTV chart requires patients to distinguish letters, though it can be easily recognizable and taught before testing [6] and 2.) In the speech recognition feature, the lay screener must verify if the system identified the inputs correctly. The study also uses image processing that incorporates the horizontal coordinate classification (HCC) algorithm and the concept of CCLRR (Central Corneal Light Reflex Ratio) in calculating the misalignment of horizontal coordinate classification of the eye to detect the presence of strabismus. The refractive error detection will utilize the principle of the Shack-Hartmann wavefront sensor together with Zernike polynomials and Fast Fourier Transform (FFT) to measure the lower aberrations (LOA) of the eyes. The device will be validated using the ISO/IEC 25010 standard.

The study will not cover the therapy and treatment of amblyopia. The device will not diagnose a patient nor replace eye practitioners; this will only serve as an accurate initial screening to identify children who need a referral to eye care specialists for treatment.

1.6 Definition of Terms

1. **Autorefraction or Autorefractor** - involves optically automated skiascopy methods or wavefront technology (Shack-Hartmann) to evaluate the refractive error of each eye
2. **Axis** – describes the lens meridian that contains no cylinder power to correct astigmatism defined with a number from 1 to 180.
3. **Cylinder (CYL)** – indicates the amount of lens power for astigmatism.
4. **Diopters (D)** – unit of measurement of the optical power of a lens
5. **Fast Fourier Transform (FFT)** – used for converting the images into the frequency domain.
6. **Hirschberg Test -** also known as a corneal light reflex test, is defined as checking the alignment of the eyes, measured by the light reflected in the eyes' corneas.
7. **HOTV** – optotypes consisting of the letter H, O, T, and V. It is used in vision assessment in preverbal children. This can be used as a matching type test where children will point to the corresponding shape on a cue card (see Figure 1A).

8. **Lea symbols** – optotypes consisting of the symbols circle, square, house, and apple. It is used in vision assessment in preverbal children. This can be used as a matching type test where children will point to the corresponding shape on a cue card (see Figure 1B).

9. **logMAR** – logarithm of the minimum angle of resolution. The letter size in a logMAR chart is described in LogMAR units where LogMAR 0.00 is equivalent to 6/6 (20/20) and LogMAR 1.00 is equivalent to 6/60 (20/200). The letter size changes in units of 0.1 LogMAR from one row to the next. LogMAR charts follow the Bailey-lovie format, which requires that: 1. Test task should be the same at each size level on the chart, which means letters should be equally legible, there are the same number of letters on each row, and there is uniform between-letter and between-row spacing; 2. There should be a logarithmic progression of letter size so that the scaling factor is constant throughout the chart and will remain unaltered when nonstandard viewing distances are used.

10. **Optotype** – the letter, symbol, or character used in a visual acuity chart

11. **Photoscreener -** Photoscreening uses optical images of the eye's red reflex to estimate refractive error, media opacity, ocular alignment, and other factors, such as ocular adnexal deformities (eg, ptosis), all of which put a child at risk for developing amblyopia

12. **Refraction** – an exam that measures the person's prescription for lenses. It can be measured by different means including subjective refraction, retinoscopy, autorefractors, or photoscreeners. When you instill cycloplegic drops in the eye to temporarily paralyze the eye before measuring refraction, this is called cycloplegic

refraction. It relaxes the accommodation of the subject and allows for more repeatable measurements.

13. **Refractive error** – a condition wherein the eye cannot focus light rays properly, resulting in a blurred image. The different types of refractive error are myopia (nearsightedness), hyperopia (farsightedness), and astigmatism (irregularly-shaped cornea or lens). Anisometropia is when there are unequal refractive errors between the two eyes.

14. **Retinoscopy -** a technique to obtain an objective measurement of refractive error The examiner uses a retinoscope to shine light into thePatient's eye and observes the reflection (reflex) off thePatient's retina.

15. **Shack–Hartmann Wavefront Sensor** – a wavefront sensor commonly used in adaptive optics systems consists of a lenslet array and a camera.

16. **Sphere (SPH)** – indicates the amount of lens power measured in diopters (D) prescribed to correct nearsightedness or farsightedness.

17. **Strabismus** – a condition wherein the eyes are misaligned, either crossed or deviated

18. **Subjective refraction** – a technique to measure refraction where you need thePatient's input to determine the best prescription. This is the standard for refraction in adult patients.

19. **Testability / testable** – in terms of visual acuity, this is the ability of a subject to complete visual acuity testing in both eyes on the first try.

20. **Visual acuity** – clarity of vision, the ability to discern small details with precision. It is measured using visual acuity charts.

21. **Zernike Polynomials** – this method is used in an optical system for unfolding the shape of an aberrated wavefront in the pupil.

CHAPTER 2

REVIEW OF RELATED LITERATURE AND STUDIES

This chapter includes the background theories, principles, and studies useful in developing the idea in conceptualizing the project. This includes technical terminologies used from the past and present projects developed.

2.1 Prevalence of Vision Disorders in Children

Amblyopia affects about 1.44% of the global population, or an estimated 99.2 million people [7]. Cubillan [8] estimates that 4 out of 40 pupils in a class have vision impairment in the country; one may have amblyopia, and three of them may have a refractive error.

In the Third National Survey of Blindness [9], refractive errors accounted for 10.3% of bilateral blindness (visual acuity worse than or equal to counting fingers at 3 meters). Refractive errors were the leading cause of low vision (vision worse than 6/18 but better than CF 3m) at 53%. Amblyopia accounted for 0.6% of bilateral blindness (1 case out of 174 bilateral blind) and 0.3% of low vision (2 out of 598). The sample surveyed in this study included subjects of all ages from the first to the ninth decade of life [9].

In other parts of the world, amblyopia estimates range from 0.8% to 2.6% among children aged 30 to 72 months [10, 11, 12]. The prevalence was not found to vary with age. Strabismus prevalence ranges from 0.80% to 3.55% among those aged 6 to 72 months, with a higher prevalence in older children [10, 11, 12]. Prevalence rates for amblyopia and strabismus did not appear to differ across racial groups.

Studies on the prevalence of error of refraction vary in their definitions, but most studies use -0.50 to -1.00D sphere as the lower limit for myopia, +3.00Dsph for hyperopia, and 1.50D sphere for astigmatism. They also use different methods of measuring the error of refraction. For example, the MEPEDS [13] and Baltimore Pediatric Eye Studies (BPEDS) [14] used the Retinomax, a handheld autorefractor, for all age groups, while the STARS study (Strabismus, amblyopia, and refractive error in Singaporean Children) [12] used a table-mounted autorefractor for their participants aged 24 months and above.

Among Singaporean children aged 6 to 72 months, the overall prevalence of myopia (at least -0.50 D) was 11.0%, with no sex predilection [12]. Myopia of at least -1.0D was found in 5.6% of participants. The prevalence of hyperopia, astigmatism, and anisometropia were 1.4%, 8.6%, and 0.6%, respectively. For astigmatism, prevalence increased with age. This was not the case with myopia and hyperopia. In MEPEDS [13], myopia (at least −1.00 D) was found in 6.6% of African-American and 3.7% of Hispanic children, with no significant difference between the sexes for each ethnic group. In the same study, Hispanics showed a higher prevalence of hyperopia than African American children (26.9% vs. 20.8%, respectively). Among children aged 6 to 71 months, the BPEDS group [14] found that the prevalence of myopia of at least −1.00 D in African-American children was 5.5% and that in Caucasian children to be 0.7%. The prevalence of myopia in their study was 8.9% in Caucasians and 4.4% in African-American children.

The MEPEDS group [15] found that visual impairment (VI) in the worse eye from amblyopia affects 1% of African-Americans and 1.4% of Hispanic children. Fifty percent of African-American children and 38% of Hispanic children with amblyopia had bilateral amblyopia. VI in the worse eye caused by amblyopia or probable amblyopia was 6.5 times more common than that caused by ocular disease (e.g., anterior segment abnormalities, corneal abnormalities). For the better eye, VI caused by amblyopia or probable amblyopia was five times more common than that caused by ocular disease. VI from unilateral amblyopia was primarily caused by anisometropia rather than strabismus (6 of 9 cases in African-American children and 13 of 15 cases in Hispanic children). Strabismic amblyopia was associated with bilateral hyperopia in 4 of 5 cases. Of all cases of amblyopia or probable amblyopia causing VI in the worse eye, 96% (50/52) were attributable to refractive error or refractive error-related strabismus. Only 4 of 23 African-American children (17%) and 4 of 29 Hispanic children (14%) with amblyopia or probable amblyopia in the worse eye already wore refractive correction [15].

2.2 Amblyopia

Amblyopia is a unilateral or bilateral reduction of visual acuity despite best correction that usually occurs in the setting of an otherwise normal eye (Wallace 2018). It is caused by an abnormal visual input early in life, such as uncorrected high refractive errors, asymmetric refractive errors between the two eyes (anisometropia), strabismus, a significant cataract, or ptosis. Unilateral amblyopia is defined by the Multi-ethnic Pediatric Eye Disease Study (MEPEDS) as a ≥ 2-line interocular difference in best-corrected visual acuity or BCVA (vision measured with glasses) with ≤ 20/32 in the worse eye and the presence of a unilateral amblyopia risk factor (strabismus, anisometropia, or visual axis obstruction), while bilateral amblyopia is defined as bilaterally subnormal BCVA <20/50 in 30–47 months or <20/40 in ≥48 months) in the presence of bilateral error of refraction or with evidence of visual axis obstruction of both eyes [16].

During the critical period, an asymmetry in the quality of the visual input across the two eyes leads to reduced visual acuity and a visually evoked spiking response through the affected eye with no obvious pathology in the eye, thalamus, or cortex [17]. The severity of amblyopia depends on the age at initiation and the type of insult. The critical period for developing amblyopia in children extends to 8 years. It is relatively easy to correct until that age by improving the quality of visual input in the affected eye [17]. This is accomplished by prescribing glasses for refractive errors, surgical removal of cataracts, and patching the better eye in unilateral amblyopia. It is believed that the visual system is sensitive to insults until four years, indicating that treatment should begin before this age [18].

2.3 Vision screening and visual acuity measurement

Vision screening is intended to detect children with treatable ocular conditions that impair visual acuity (VA), such as refractive error, amblyopia, and strabismus. It may also detect serious but rare ocular conditions, such as retinoblastoma, that otherwise would have gone undetected.

To prevent visual impairment, vision screening should be performed early and regularlyhroughout childhood [5]. Cubillan et al. [19] recommend the following for vision screening in children at school entry (many of whom will be five years old): 1. Vision screening for amblyopia and strabismus is recommended for all children at least once using an age-appropriate chart. 2. Screening infants at six months of age for ocular problems, at age 2-3 years, at five years, and every 1 to 2 years after that for visual acuity and ocular alignment may be done. The study recommends the Lea chart because it is validated, has undergone repeated calibration, and symbols are easy to recognize across cultures [19]. However, Lea symbols are copyrighted and cannot be reproduced without approval [20].

While there is no gold standard in terms of visual acuity charts for the pediatric population, the preferred optotypes are Lea symbols, Sloan letters, and HOTV because they are standardized and validated [5]. Testability improves with age, regardless of which optotype is used [21]. Testability for the Lea and HOTV charts is greater than 90% among 5-year-olds [22] [23] [24]. Lea is easier to use in children aged 3 [22].

It should be noted that the studies used different formats of the HOTV chart. The VIP study group [22] used linear HOTV surrounded by a crowding bar 0.5 optotype-width (half a letter) away. Interoptotype distance averaged 1-optotype width (see Figure 1). Leone et al. [23] used an electronic visual acuity (EVA) tester with ATS HOTV optotypes (i.e., computerized version of the ATS HOTV) and the CSV-1000 (i.e., illuminated viewer) HOTV chart. They compared the two against the ETDRS chart (see Figure 2). Holmes et al. [24] used the ATS HOTV. Moke et al. [25] used a computerized version of the ATS HOTV (see Figure 2a.). The ATS HOTV is a chart developed for the amblyopia treatment studies (ATS), a group of trials conducted by investigators from The Pediatric Eye Disease Investigator Group (PEDIG) that has significantly influenced and altered amblyopia practice patterns for many eye care providers. PEDIG is a network of pediatric optometrists and ophthalmologists funded by the National Eye Institute to perform clinical research on pediatric eye conditions [26]. The ATS chart consists of single HOTV optotypes surrounded by crowding bars at a 0.5 optotype-width distance (see Figure 3). Single optotypes (without crowding) can underestimate the degree of amblyopia compared with linear charts.

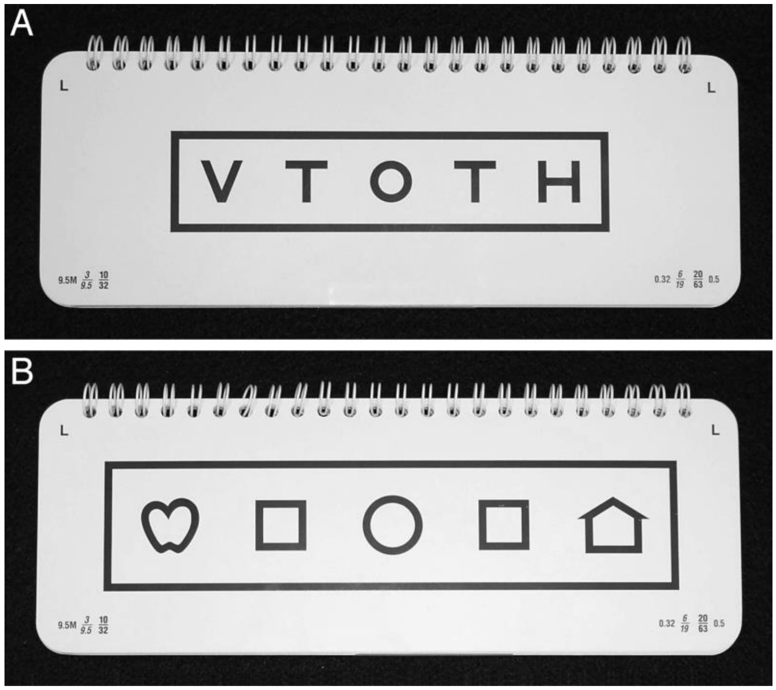


Figure 1. **Charts used in the VIP Study (2004).** A. HOTV chart B. Lea chart

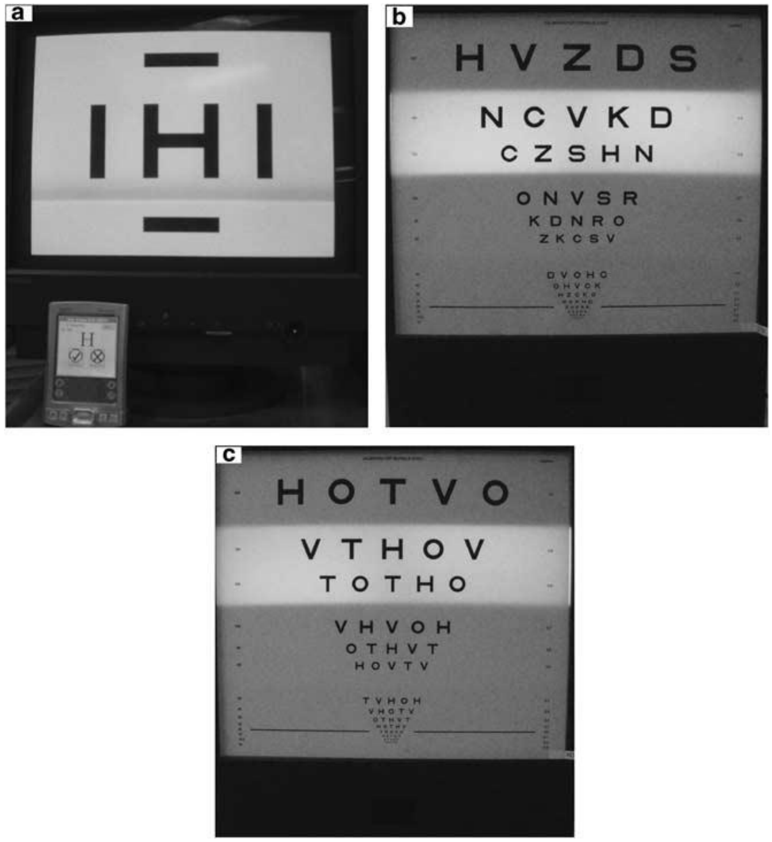


Figure 2. Charts used by Leone et al (2012). (a) computerized ATS HOTV visual acuity testing protocol, (b) LogMAR chart displaying the CSV-1000 (illuminated viewer) EDTRS test plate, and (c) the LogMAR chart displaying the CSV-1000 HOTV test plate.

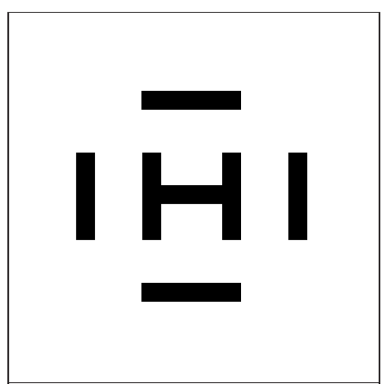


Figure 3. **Single-surround optotype used in the ATS HOTV** [24]

According to Hered et al. [21], visual acuity measurements obtained with the Lea and HOTV charts are comparable, but the HOTV tends to give a slightly worse visual acuity among 3-year-olds. Leone et al. [23] found that average ATS HOTV visual acuity was worse by 0.1 logMAR compared to linear HOTV. Rice et al. [27] found that ATS HOTV visual acuity was better than an electronic crowded ETDRS chart with a mean difference of 0.06 logMAR (approximately three letters). Interestingly, in the same study, testability for the ETDRS chart was 52% among 5-year-olds and 100% in children seven years and older.

For their versions of the HOTV chart, Sprague et al. [28] and Holmes et al. [24] report a test-retest agreement of 0.1 logMAR (within 1 line difference) in 98% and 93% of subjects, respectively. Similarly, Moke et al. [25] reported that 88% of right eye retests and 94% of left eye retests were within 0.1 logMAR units of the initial test. Harvey et al. [29] found that the inter-observer agreement for the assessment of visual acuity when the results for the HOTV and ETDRS are combined was about 0.15 logMAR (1.5 lines) or better in 71% of eyes and 0.3 logMAR (3 lines) or better in 93% of eyes. According to Moke et al. [25], a real difference is certain only if it is two or more logMAR levels.

Moke et al. [25] calculated the 95% confidence interval for an acuity score to be the score ± 0.13 logMAR units, whereas for a change between two acuity scores, the 95% CI was the difference ± 0.19 logMAR units. In the study by Holmes et al. [24], the 95% confidence interval for an acuity score with the ATS HOTV was ± 0.125 logMAR units. For change between 2 acuity scores, the 95% CI was ± 0.18 logMAR.

To test the agreement between different methods of visual acuity measurement, most studies use the Bland-Altman assessment [30]. This method also allows analysis of the repeatability of a single measurement method or to compare measurements by two observers. The VIP group [22] used the Cochran Q test for marginal homogeneity to compare the distribution of results from the two visual acuity tests and the Wilcoxon signed-rank test to detect a shift between the two VA methods.

As mentioned earlier, visual acuity testing is more challenging to perform in children less than three years of age. For this reason, the preferred methodology for children less than four years old is instrument-based screening using photoscreeners or autorefraction [31]. In children older than five years, visual acuity testing using vision charts can be used reliably and should be performed every 1 to 2 years [31]. For children, 4 to 5 years of age, photoscreening and autorefraction are not superior or inferior to visual acuity testing with vision charts [31].

2.4 Refraction

Refractive errors are the most common cause of amblyopia. Giordano et al. [14] found that 5% of children aged six months to 6 years would have benefited from refractive correction.

Cycloplegic retinoscopy, with subsequent cycloplegic subjective refraction is considered the historic gold standard for refraction measurement in children [32]. It can take much time and can only be done by experienced eye care professionals. It is therefore not routinely performed in vision screening. On the other hand, autorefractors can take multiple measurements quickly, are objective, and do not require highly trained personnel. For this reason, they have gained popularity in-clinic use and in research.

Wilson et al. [32] reviewed the accuracy of autorefraction in children and evaluated 15 studies. They found that autorefractors tend to underestimate hyperopia and overestimate myopia by 1 to 2 D under non-cycloplegic conditions. When comparing cycloplegic autorefraction and cycloplegic retinoscopy, the mean difference for sphere was less than 0.5D in 11 of 15 studies. When comparing autorefraction without cycloplegia and cycloplegic refraction, the mean differences were more variable, ranging from -2.11 to + 0.13 D. The mean differences in cylinder power in all studies except for one study was 0.25 D or less. However, the individual variability for sphere and cylinder power was still vast. In summary, their study concludes that cycloplegia improves the accuracy of autorefraction measurements and that cycloplegic retinoscopy helps confirm the results of cycloplegic autorefraction [32].

Sanchez et al. reviewed photoscreeners and evaluated 11 devices [33]. Handheld photoscreeners were found to underestimate hyperopia and overestimate myopia according to spherical equivalent when their outcomes were compared with cycloplegic retinoscopy. They conclude that the estimated refraction from photoscreeners is unsuitable for the final prescription. Their advantage in screening is that they require a shorter time than autorefractors to take measurements, and some devices include further analysis of eye misalignment, ptosis, or lens opacity [33].

Schmidt et al. [34] and Ying et al. [35] evaluated the sensitivities of 11 commonly used preschool vision screening tests at 90% and 94% specificity, respectively. Schmidt et al. [34] reported that at 90% specificity, noncycloplegic retinoscopy had the highest sensitivity to detect one or more eye conditions (64%). In comparison, Lea and HOTV charts' sensitivities were calculated at 61% and 54%, respectively. The cover-uncover test had very low sensitivity (16%) but high specificity (98%). Ying et al. [35] set the overall specificity to 94% and found that noncycloplegic retinoscopy had the highest sensitivity for detection of amblyopia (88%) and significant refractive error (74%). Lea symbols test had a 58% sensitivity for detecting refractive error and 48% sensitivity for detecting decreased visual acuity. Unlike administering visual acuity tests, noncycloplegic retinoscopy and cover-uncover testing require training and experience and may be challenging in programs involving untrained personnel.

Donaghue et al. [36] report that vision screening using logMAR acuity can detect myopia but not hyperopia or astigmatism in school-age children. To detect amblyopia, preschool vision screenings may include a refractive error, visual acuity testing, and tests to detect strabismus. The Vision in Preschoolers Study Group [37] tried to determine the effect of combining screening for eye alignment with a refractive error or reduced VA on sensitivity for detecting strabismus. They found that the most efficient and low-cost way to achieve a statistically significant increase in sensitivity for detecting strabismus was by combining the unilateral cover test with the autorefractor (Retinomax) administered by eye care professionals and by combining Stereo Smile II with SureSight administered by trained lay screeners.

In general, the decision as to what tests to include in screening should be based on the program's goals and resources, keeping in mind expert recommendations.

Comparisons between refractive error measures (the mean difference, standard deviation, and 95% confidence limits) can be calculated using paired two-tailed t-tests and presented graphically using Bland-Altman plots [38] .

2.5 Shack-Hartmann Technology and Virtual reality

Autorefractors and photoscreeners can be expensive, so they may not be feasible for many schools, pediatricians, or eye care practitioners.

Refraction using wavefront technology has been shown to be feasible, accurate, and inexpensive. When visual acuity from autorefraction with a device using Shack-Hartmann technology was compared to visual acuity (VA) from subjective refraction, VA was worse by only 1 line. [39]. Investigators from MIT were able to develop a portable autorefractor utilizing inverse Shack-Hartmann technology [40]. However, these devices can typically only detect low to moderate refractive errors. Ciuffreda and Rosenfeld [38, 41] evaluated a portable, Hartmann-Shack wavefront aberrometer (SVOne), which can be attached to a smartphone to measure refractive error. Measurements taken with the SVOne were comparable to those measured by other means, including retinoscopy, subjective refraction, and two commercially available autorefractors (Topcon KR-1W and Righton Retinomax-3).

Encyclopedia Britannica defines virtual reality as such [42] : “Virtual reality is the use of computer modeling and simulation that enables a person to interact with an artificial 3D visual or other sensory environment. VR applications immerse the user in a computer-generated environment…. In a typical VR format, a user wearing a helmet with a stereoscopic screen views animated images of a simulated environment. The illusion of “being there” (telepresence) is affected by motion sensors that pick up the user’s movements and adjust the view on the screen accordingly, usually in real-time (the instant the user’s movement takes place). Thus, a user can tour a simulated suite of rooms, experiencing changing viewpoints and perspectives that are convincingly related to his head turnings and steps.”

Commercial companies have used virtual reality (VR) to perform eye tests. Media Medical Solution [43] has reportedly developed five eye tests, including a color vision test, visual acuity test, and astigmatism test. However, there is no published data regarding the accuracy or validity of their tests. M&S Technologies has also developed the

Smart System VR Headset, which can perform visual field, contour stereo testing, and fixation monitoring [44]. VR has been used for numerous other ophthalmology applications, including education, diagnosis, functional assessment, and therapy [45]. Most applications involve surgical simulators for cataracts, vitreoretinal procedures, laser trabeculoplasty, and corneal laceration repair. There were also applications for heads-up surgery, binocular treatment of amblyopia, functional improvement for the visually impaired, and aid for achromatopsia.

CHAPTER 3

METHODOLOGY

3.1 Theoretical Framework

Figure 4. **The Theoretical Framework of the Study**

The figure shown displays the relevant studies which support the research study. According to a study, amblyopia is one of the most prominent causes of vision impairment globally, especially in children [46]. In observance of the research findings in [47], VR technology in amblyopia therapy improves the patient's compliance, and the game is perceived as a fun alternative to conventional treatment. This study will also make use of VR technology as a device to detect Amblyopia in children. Patients aged 5 to 6 may already develop amblyopia [48], so the screening is the most sensitive for this age group. The device will perform three standard tests, including the visual acuity test, the light reflex test, and refractive error detection. The preferred optotype to be used in the visual acuity test is HOTV because of its high testability and low false-positive rate [49]. This test will be integrated into a 3D animation to create an environment like VR games. In refractive error detection, a wavefront sensor will be used to detect the aberrations of the eye [50] and Zernike polynomial fitting as its processing method [51]. The light reflex test will specifically detect strabismus amblyopia and will be implemented using digital image processing and an algorithm to calculate the misalignment of the eye [52]. All the data will undergo processing in the microcontroller (Raspberry Pi 4) [53], and the result will be reflected on a website [54]. All the concepts and principles of the studies mentioned above are merged into a research idea. Thus, the researchers came up with the study entitled - iVRead: Interactive Virtual Reality for Early Detection of Amblyopia for Kindergarten Pupils.

3.2 Conceptual Framework

3.2.1 Block Diagram

INPUT

KNOWLEDGE REQUIREMENTS:

1. Programming in Python, C#, and JavaScript.

HARDWARE REQUIREMENTS:

1. Head-mounted Virtual Reality (VR)
2. Pi Camera
3. Raspberry Pi 3B
4. Shack-Hartmann wavefront sensor
5. Visual Stimulus

SOFTWARE REQUIREMENTS:

1. Unity-3D (C#)
2. Spyder (Python)
3. Android studio (JavaScript)
4. Tinkercad

PROCESS

HARDWARE DEVELOPMENT:

1. Designing and Assembly of VR Box in Tinkercad.

SOFTWARE CONSTRUCTION:

1. Designing of 3D software application for audio-visual animation
2. Flowcharting and Programming of android application for control panel overlay
3. Creating an algorithm that will measure the refractive error and eye alignment
4. Development of website

TESTING AND EVALUATION:

Validity Testing and ISO/IEC 25010 Standard

OUTPUT

Detection of the presence of Amblyopia risk factors: visual acuity, eye misalignment and refractive error.

Figure 5. **IPO Model of the Study**

The figure shown above is the Input-Process-Output (IPO) model of the study. The study's general objective is to develop a device that will measure eye alignment, refractive error, and visual acuity. The input will be the response and data from kindergarten pupils in all three tests using the VR device. The visual acuity test will use a 3D software application with audio-visual animation. Then, an android application will be used as the system's control panel. The microprocessor will process the acquired data from the visual acuity test, and the device will display the patient's VA with correction. The device will measure the misalignment of the eye in a light reflex test and identify the presence of strabismus. And then, the measured refractive error will be processed using an algorithm to determine the type of refractive error. Overall, the device will detect if there is a presence of amblyopia risk factors in the patient.

The results of the individual patient will be reflected on the website. Comparative testing is used to test the device, and ISO/IEC 25010 standard evaluates the system by experts and stakeholders.

3.2.2 System Architecture

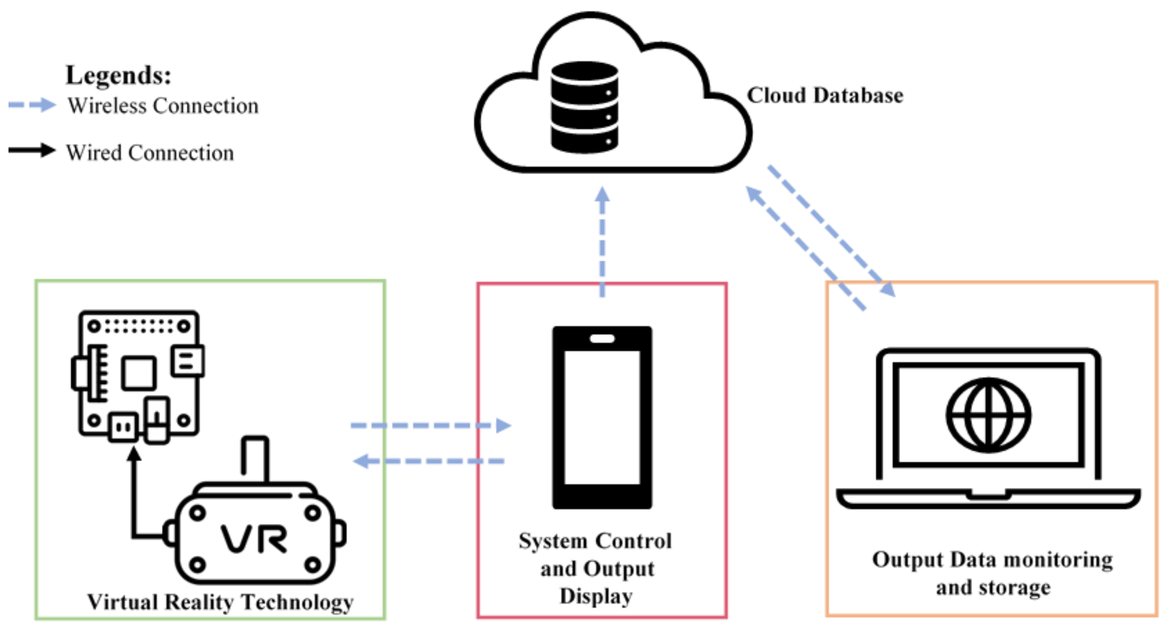


Figure 6. **System Architecture**

Virtual reality technology-based vision screening incorporated with the mobile application system architecture is shown in Figure 6. The vision screening exams are merged in a VR processed by 2 Raspberry Pi 3B with a mobile application panel. The mobile app serves as telemetry and control for the system to display and transmit data to the database automatically. VR and mobile controllers communicate wirelessly through built-in Wi-Fi in the Raspberry Pi. The mobile application uploads the data to cloud storage via an internet connection. Authorized personnel can access data results on a website. It will also be designed so that the doctor can input remarks based on the results of the patients.

3.3 Research Design

3.3.1 Hardware Design

3.3.1.1 Schematic Diagram

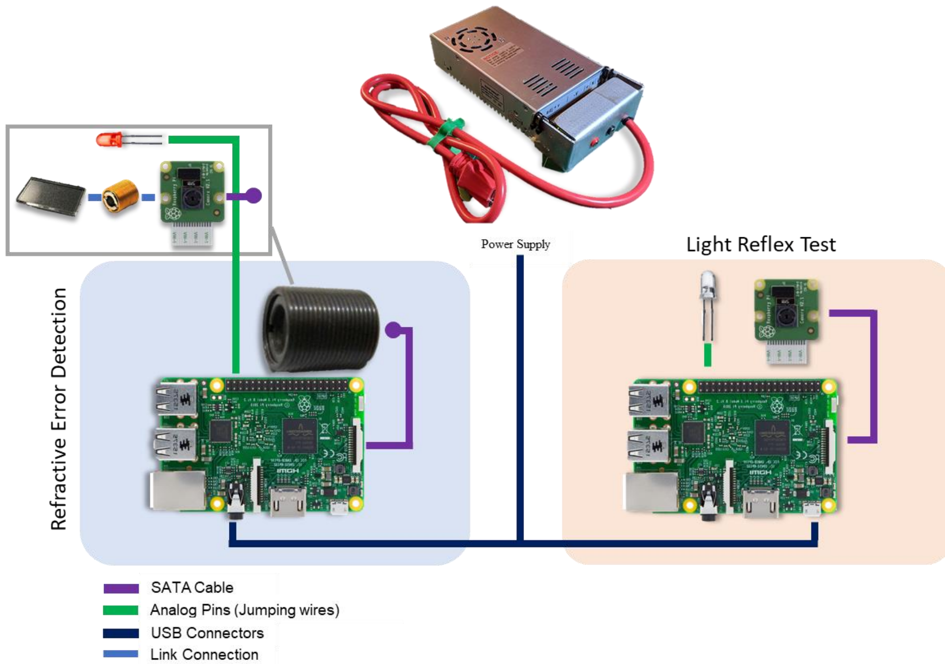


Figure 7. **Schematic Diagram of the VR**

The device will use two microprocessors (2 Raspberry Pi 3B). The Raspberry Pi are programmed to process the algorithms of all the tests. Python and Java languages are added to its library to adapt the codes needed for the output display. Python is also used to utilize the program for other input devices such as the wavefront sensor for the refractive error detection, white LED for the light reflex test, and pi camera for refractive error detection and light reflex test.

A schematic diagram of the microcontroller, the input and output devices used, and the connections are shown in Fig. 7. A USB 2.0 connector is used for data transmission and power supply. The processed data will be transmitted from the Raspberry Pi to the IoT-based web application through the microprocessor's built-in ethernet. The whole system uses a 5V and 10A rating power supply.

3.3.1.2 Hardware Construction

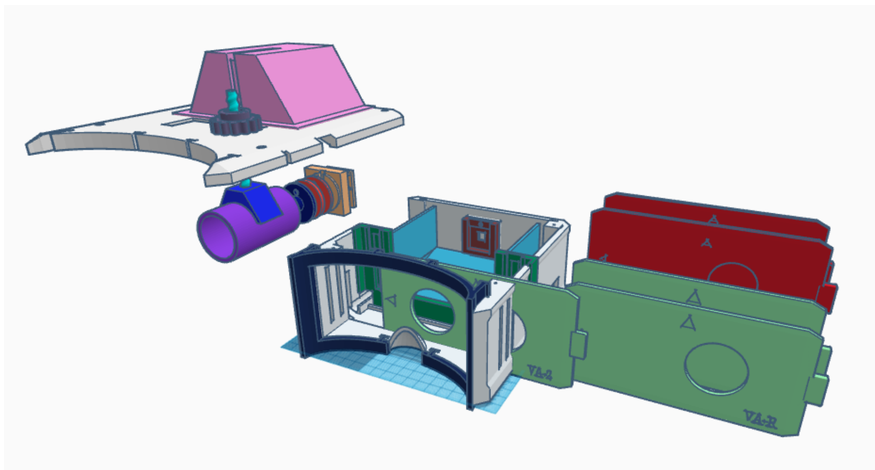
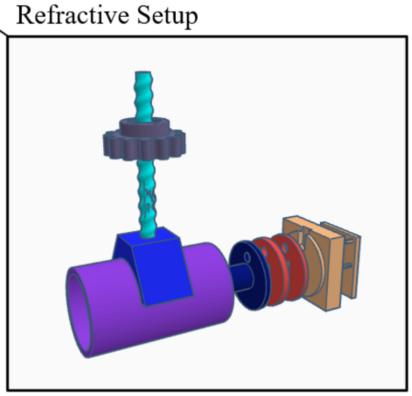


Fig 8. **Prototype Design of iVRead**

PARTS

- Foam Cartridge – it is where the foam is attached.
- Light Reflex Setup – holds the camera and LED.
- Panel Support – supports the base and holds the components at its side.
- Phone Holder – holds the phone used for visual acuity testing.
- Refractive Eye Cover – eye covers used for refractive error detection.
- Refractive Setup



Shack Hartmann Wavefront Sensor contains Collimating lens, Microlens Array, Raspberry Pi, Red LED light, and Camera

- Tube
- Tube Support
- Collimating Case
- Microlens Array Case
- Camera Case
- Rod – holds the tube and serves as the adjuster.
- Knob – to tighten or loosen the adjuster.

- Refractive Socket – Hides the refractive setup when it is unused.
- Visual Acuity Eye Cover – eye covers used for visual acuity testing.
- VR Box – holds all the components of the device.

iVRead is designed to perform three tests in a single, compact device. Figure 8 shows the intricate parts of the device, and the legend describes the function of every part.

3.3.2 Software Design

3.3.2.1 3D Software Application

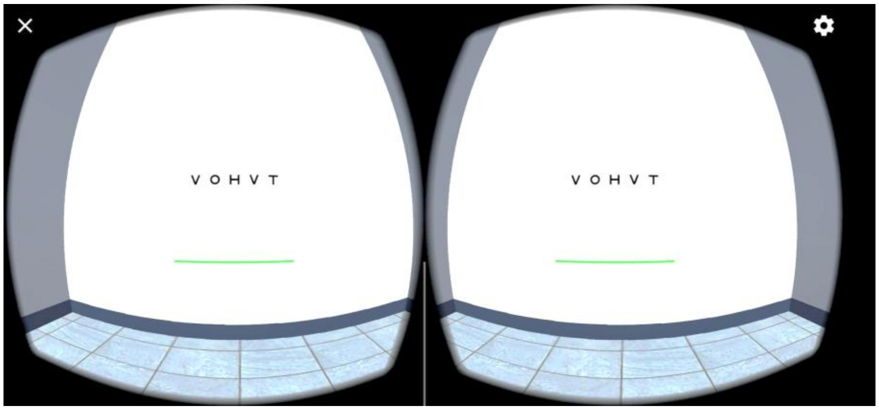


Figure 9. **3D Software Application**

In the visual acuity test, the 3D software application is programmed in the platform called Unity 3D, which uses C# as its scripting language. ThePatient will read the HOTV chart in a virtual white room having a virtual distance of 20 ft, as shown in figure 9. The optotypes will be displayed line by line. The patients are instructed to read the letters once the green line appears on the screen's lower side. The green line means that the speech recognition is activated.

The usage of scaling is crucial since the distance is relevant in performing the Visual Acuity Test. In VR animation, scaling is implemented to make the virtual reality's distance appear similar to reality. The scale and units play a vital role in creating a believable "scene," or much more known are the “real world” setup, and 1 Unity unit is equivalent to 1 meter (100 cm) [55]

Since the visual Acuity test is used in determining the smallest letters that are readable at a distance shorter than 20 feet (6 meters) [56] With that, six unity units are used to provide an accurate distance parallel with the “real world” setup distance. Since the test is implemented through virtual reality technology, the test is utilized in a mobile application.

It is advisable to read in a white background due to the reflection; irises do not need to open as wide to absorb the white light, which leaves irises in a neutral position and allows the eyes to see with better clarity, which is especially true when white light is contrasted against black, which absorbs wavelengths instead of reflecting them [57]. Although there is no significance in the relationship between visual acuity (VA) and background colors, it will still affect how irises react to backgrounds used on gadgets [58].

3.3.2.2 System Control Panel (“iVRead Controls”)

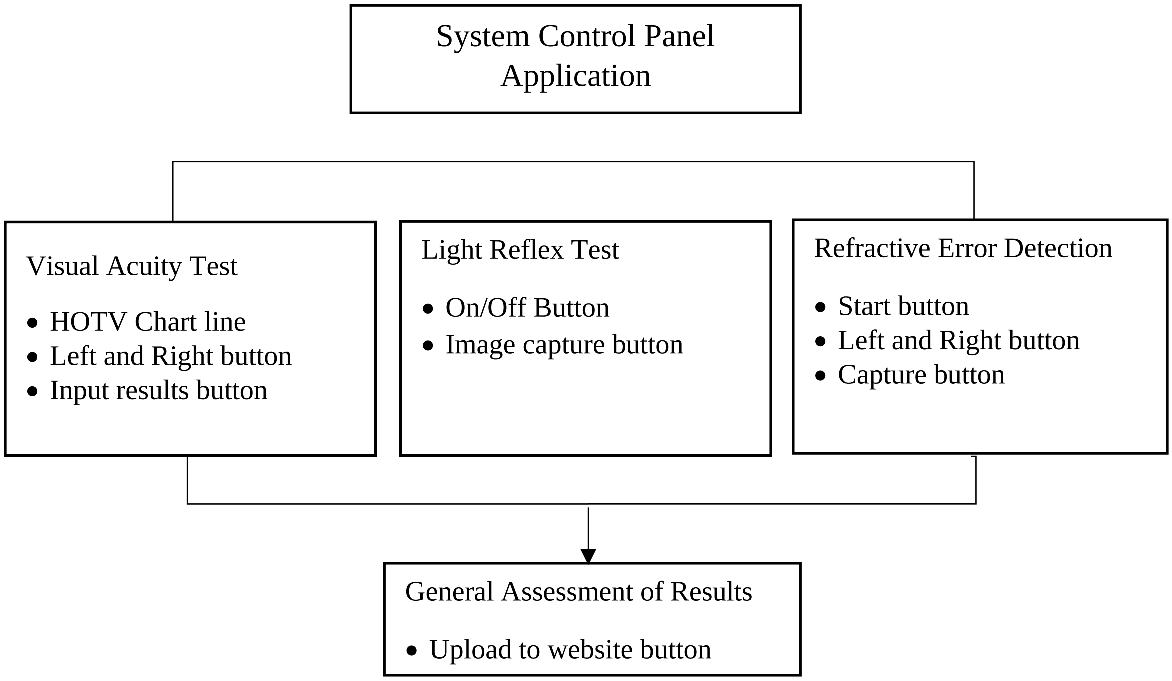


Figure 10. **Software Development for System Control Panel**

The iVRead app will serve as the control panel for the system. This app is programmed in Android Studio, which uses JavaScript as its language.

In the visual acuity test, users will read the optotypes line by line in the HOTV chart displayed on the VR screen. The patient's response is automatically recorded via speech recognition or the speech-to-text API of Google. The examiner will be able to consider or not consider the recorded inputs of the speech recognition system. Once the test is done in one eye, a button will be pressed, the left or right button, to test the other eye. Each line in the HOTV chart corresponds to a specific visual acuity depending on the number of correct responses.

Moreover, in the light reflex test, the controls consist of the start, capture, finish, and process results button. To start the process, the penlight must be powered on. Once the penlight is on, capturing the image will proceed; after that, the finish button must be pressed to turn off the penlight. The raw image captured will be processed, and the result will display the degrees of misalignment of each patient's eyes and if the patient is predicted to have strabismus.

Lastly, the refractive error detection. The controls consist of the start, left eye, right eye, and capture button. The tube will move to the desired eye using the left and right buttons. Note that this test requires a dim environment as it involves visual stimulus. Once the start button is pressed, a light (red LED) will flash, and eye-capturing will automatically occur. The same procedure will be done on the other eye. This test will produce a result of what possible type of refractive error the patient has and if the patient is recommended to see a Pediatric Ophthalmologist.

3.3.2.3 Website

The proponents will use Wix to create the website and Firebase for the database of the data gathered from the device. The Firebase Realtime Database is cloud-hosted. Data is stored as JSON and synchronized in real-time to every connected client. Applications built with this platform receive a real-time update with the newest data changes.

Google Apps Script, a coding language based on JavaScript, is also incorporated in the google sheet to automate tasks and the real-time transfer of data from the app to the website.

3.3.3 Algorithms

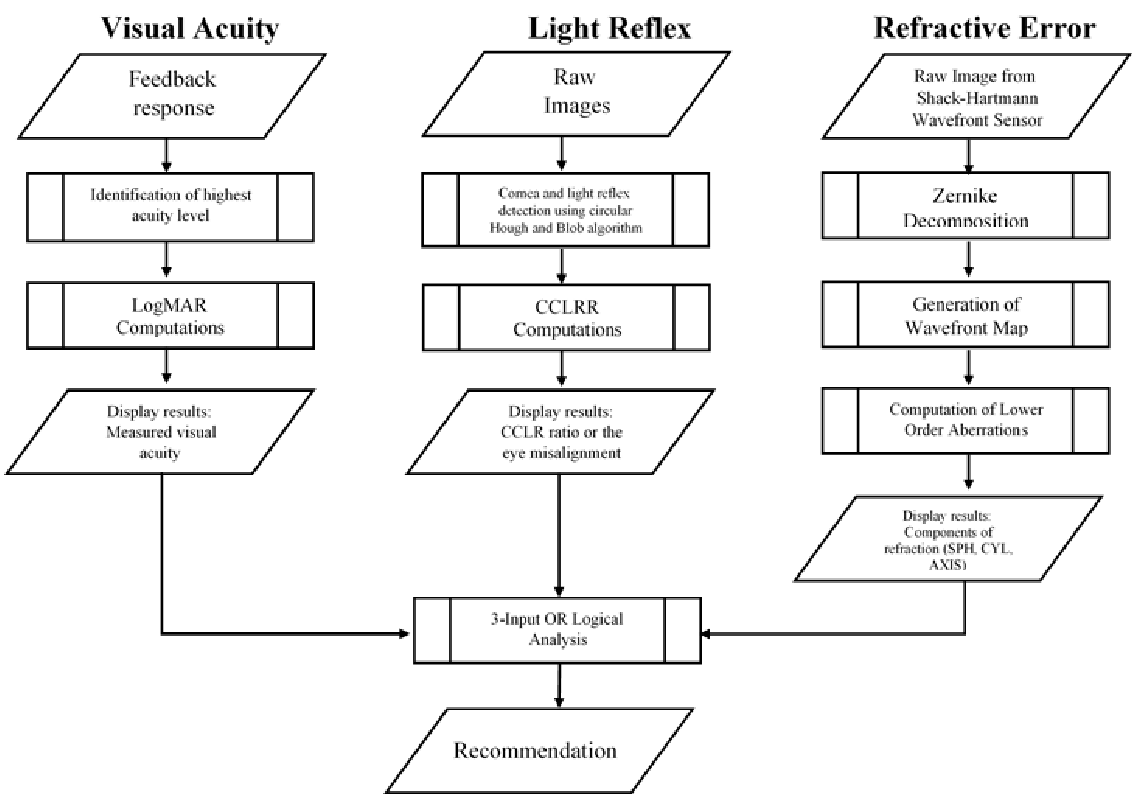


Figure 11. **Overall System Algorithm**

Python language will be used for the algorithms. Python is a high-level and general-purpose programming language used for various purposes like image and signal processing.

For the visual acuity test, the patient's response will be automatically identified via voice processing. Visual acuity is a ratio based on the smallest line of optotypes the patient can read. Starting two lines above the threshold or the last line that failed in the previous test, subjects will read progressively smaller optotypes until they fail. Failure is defined as getting more than two optotypes wrong in a line. A line is passed if at least 3 optotypes were identified in the line. The visual acuity will be recorded per eye in logMAR units.

Table 1. Visual Acuity Threshold for children aged 5-7

Parameter	Threshold (logMAR)
Normal Vision	≤ 0.18
Abnormal Vision	> 0.18

There is a standard visual acuity threshold for every age group. For children aged 5-7 to pass the visual acuity test, their visual acuity must be greater than 20/30 ft or 0.18 logMAR [59]. Those who have do not meet the age-specific criteria for each eye should be recommended to see an ophthalmologist for their vision to be corrected. The result displayed in this test is the visual acuity with its corresponding correction.

The algorithms used for the light reflex test are circular Hough and Blob Algorithm. First, the raw image will undergo gray scaling and image thresholding, then the Circular Hough algorithm to detect the eye's cornea, and the Blob algorithm to detect the light reflex in the eyes. To detect strabismus, there must be a misalignment in the light reflex in both eyes. To determine if there is a misalignment, the CCLRR value will be computed.

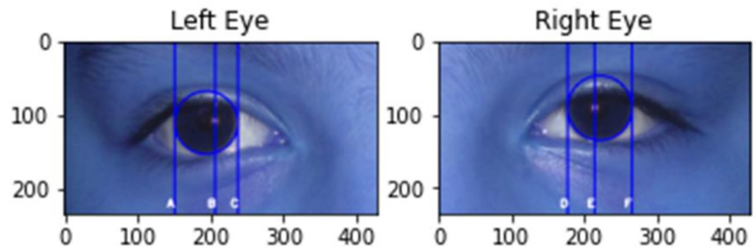


Figure 12. **Sample Coordinates Placement Result of Right Eye and Left Eye** [60]

The formula to compute for CCLRR value is:

$$\text{CCLRR} = \frac{BC+DE}{AC+DF} \tag{1}$$

To check if the patient has No Strabismus or With Strabismus, the CCLRR value obtained is compared to the reference CCLRR values in Table 2.

Table 2. Normal and abnormal ranges of CCLR in young adults with mean ages of 16 to 20 years [61]

Parameter	Measurement
Normal range	0.448 – 0.488
Abnormal range	< 0.440, >0.497

If the patient has no misalignment in the eyes, the patient is considered to have a normal vision. If the patient has a misalignment in the eyes, the device will display that patient possibly has strabismic amblyopia and is recommended to see a Pediatric Ophthalmologist.

For refractive error detection, an algorithm will process the raw image captured from the Shack-Hartmann wavefront sensor by reducing the noise using Gaussian filtering for the refractive error. The median filter will also be applied to improve the image further. After these processes, Fast Fourier Transform will be used to reconstruct the filtered image. This moves the DC frequency to the center. The magnitude and phase spectrum of the transformed image is generated, and two peak values surrounding the central frequency are obtained. These values are correlated and used for the aberration metric, with the magnitude as rho (ρ) and the phase as theta (θ). The correlations of these two values will be used in some mathematical computations using Zernike polynomials. From these, the values of the refractive errors of the eyes are obtained. These are the spherical (SPH), cylindrical (CYL), and axial (AX) values, respectively.

Table 3. Refractive Error Type based on Spherical and Cylindrical Values

SPH Values		**CYL Values**	
Type	**Refractive Errors (diopters)**	**Type**	**Refractive Errors (diopters)**
Myopia	< -2.00	Astigmatism	< -1.50
Hyperopia	> +2.00		

The spherical value specifies if the patient has either myopia or hyperopia. Prescriptions with myopia or nearsightedness manifest a negative number while prescriptions with hyperopia or farsightedness manifest a positive number which indicates the amount of refractive error present. The cylindrical value specifies if the patient has some form of astigmatism. The axis indicates the orientation of astigmatism. This number will be between 0 to 180 degrees and can change over time. The patient is said to have normal vision if they pass the test, meaning they did not qualify for any refractive error criteria. If the patient fails the test, the device will classify the possible type of refractive error the child has and recommend it to an

Ophthalmologist for further examination. Having refractive error does not mean the patient has automatically had amblyopia. Other factors can cause refractive errors, but anisometropia is one of the closest clues to amblyopia.

After the vision screening tests, the overall assessment for recommendation will use a 3-input OR logic analysis to determine if the patient has an amblyopic or a normal eye. The inputs for logic analysis will be based on the output of each test, wherein “normal” is equal to logic 0, and “amblyopic” is equal to logic 1. If the patient was detected to have an amblyopic eye on one of the three tests, the patient will be marked as amblyopic and recommended to be assessed further by the doctor.

3.3.4 Program Flowchart

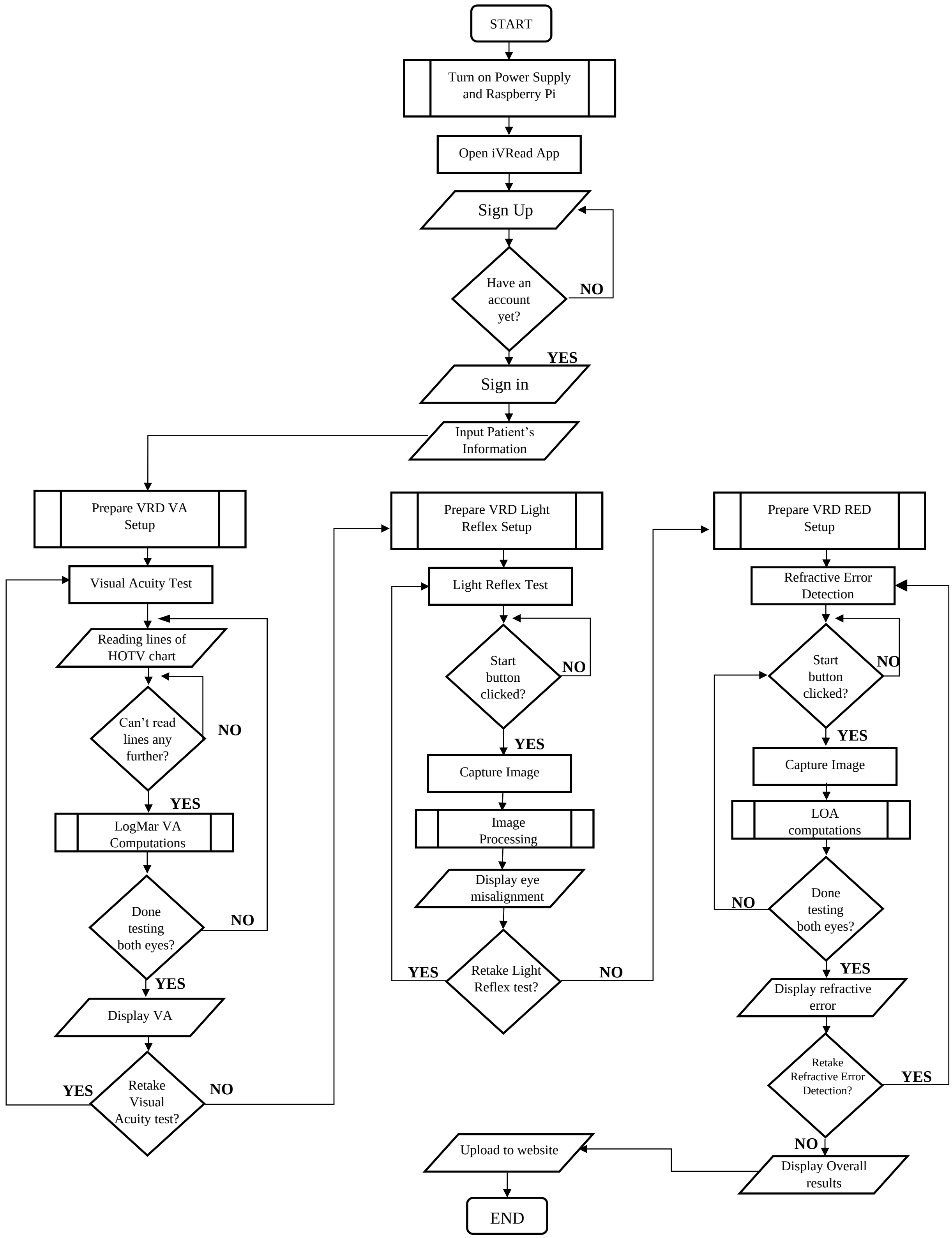


Figure 13. **Program Flowchart**

The figure shows the program of the system and its feedback for every step. The initialization of the system varies on the individual part of the vision screening. In the visual acuity test, the wireless connection must be established a few seconds after switching the processor. The audio-visual animation display will play simultaneously on the LED screen and in the control panel app on the mobile device. After that, a light reflex test will be initiated. The on/off button will control the power of the penlight. A capture button in the control panel will trigger the camera. The raw image will be processed to calculate the degree of misalignment of the eye and to determine if thePatient has strabismic amblyopia. The Raspberry Pi will transmit the result, including the images, through a wireless connection to the mobile device. The results will also be reflected on the website when the mobile device has an Internet connection. The Refractive error detection tube will proceed with assessment by flashing a red LED and capturing the image for wavefront mapping. The Raspberry Pi will process the image and convert it into numerical results with a recommendation on what type of refractive error the patient has; in case of malfunction, the program restarts to check the initialization procedure of every peripheral.

3.3.5 Equipment and Materials

3.3.5.1 Microlens Array

Figure 14. **Raspberry Pi 3B** [62]

The Raspberry Pi 3B model is a computer that can operate and use programming for practical projects and is a smaller, more energy-efficient machine. The Raspberry Pi 3B is the earliest third-generation model of Raspberry Pi. The power source is up to 2.5V through micro-USB. It is a Quad-Core 1.2GHz Broadcom BCM2837 64bit CPU with a MicroSD slot for storing data and loading the operating system. It has available different ports like CSI camera port for connecting Raspberry Pi Cam and DSI display port for Raspberry Pi touchscreen display. The weight of the Raspberry Pi 3 Model B is 42 grams.

3.3.5.2 Power supply

The power supply that will be used is a Xiaomi two-way fast charging power bank with a battery capacity of 10,000mAh. The power bank weighs 0.250kg and has dimensions of 130 x 71 x 14.1mm. The battery type is a lithium polymer battery with a rated capacity of 38.5 Wh.

3.3.5.3 Microlens Array

Figure 15. **Microlens Array**

Microlens array uses to examine the wavefront alignment at many points across the area. It is more efficient when collecting light and provides spots that are either smaller or bigger; however, it is essential for the low-light application. In a Shack-Hartmann, the focal length of the microlens array is proportional to its sensitivity. The substrate material used is Fused Silica (Quartz) with a 10 by 10 mm square grid dimension. The applicable wavelength range is from DUV to IR.

3.3.5.4 Collimating Lens

Figure 16. **Collimating Lens** [63]

The word 'Collimating' precisely aligns the light array into a parallel beam of light. The light that enters will produce accurate analysis, designed to reduce the divergence angle.

3.3.5.5 USB Camera

Figure 17. **USB Camera** [64]

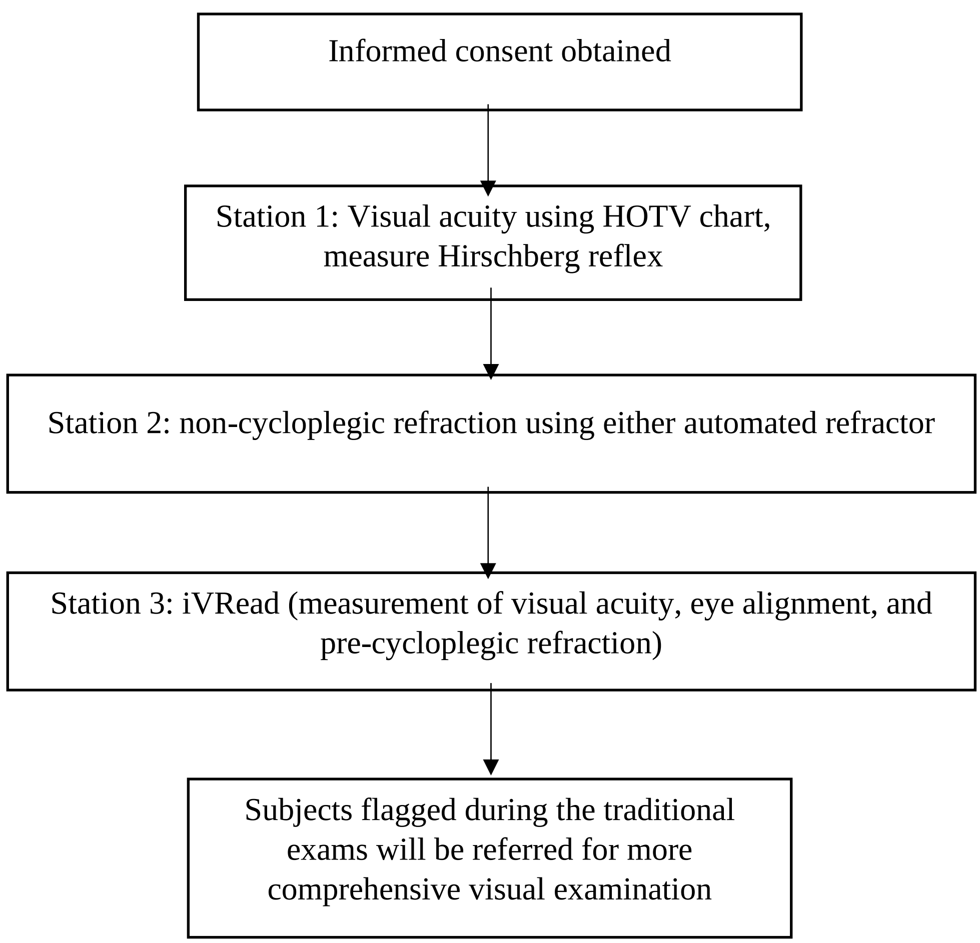
USB Camera will be an optical instrument used to capture the eyes for the light reflex test and refractive error detection. The minimum illumination of the USB camera will be used 0.2 lux. The camera resolution is 12 megapixels with an image size of ¼ inch and a 480p resolution. The operating voltage is 5V DC, and the operating current is 100mA to 160mA. The PCBA dimension is 20 by 20mm. The weight is 6.8 grams.

3.3.5.6 Smart phone

The screen display to be used in the 3D visual acuity is a Xiaomi Mi 11 Lite smartphone with 8GB RAM and 128GB ROM. The weight of the smartphone is 157g. It has an AMOLED screen display which consumes less power and provides the capability to give more vivid picture quality compared to LCD. Moreover, it has dimensions of 6.32 x 2.98 x 0.27 in.

3.4 Testing Procedure

To determine the device's accuracy, the result from the VR device tests will be compared to the result from traditional eye exams performed by an Ophthalmologist. Patients will be assigned participant codes. They will undergo three tests: visual acuity, alignment, and refraction. Each participant will undergo both traditional and virtual reality device (VRD) testing. Figure 13 shows the flow of examination. It will take about one and a half hours for the participant to complete all tests. Table 1 shows the findings or the values that will flag a participant who may have an eye condition and thus need a comprehensive eye examination.



- Retesting will be done for all steps by the same or a different examiner

Figure 18. **Testing Procedure Flow**

3.4.1 Visual acuity testing with the HOTV chart

A. Testability

Subjects will be tested binocularly to see whether they can identify all the letters in the HOTV chart. Then testing will be done monocularly. With the left eye occluded, the subject will try to identify one optotype per line and go through progressively smaller lines until he or she cannot identify the optotype. The same will be done for the other eye. A subject is considered testable if he can complete testing in both eyes.

B. Measurement of visual acuity

Starting two lines above the threshold or the last line that failed in the previous test, subjects will read progressively smaller optotypes until they fail. Failure is defined as getting more than two optotypes wrong in a line. A line is passed if at least three optotypes were identified in the line. The visual acuity will be recorded per eye in logMAR units.

C. Retest

After a few minutes, visual acuity will be remeasured by another examiner. This is to calculate test-retest reliability.

3.4.2 Hirschberg Testing

An experienced pediatric ophthalmologist will examine the corneal light reflex to determine if strabismus is present and, if so, to measure the amount of eye deviation. Each millimeter of decentration of the light reflex from the center of the pupil is equivalent to about 7 degrees or 15 prism diopters of deviation. After a few minutes, Hirshberg testing will be repeated by the same examiner.

3.4.3 VR Device

Visual acuity, measurement of eye alignment, and pre-cycloplegic refraction will be performed using the VR device. The developer of the VR device will conduct the testing. Visual acuities will be measured one eye at a time, while eye alignment and refraction will be measured binocularly.

A. Testability

Before conducting the visual acuity test, subjects will be assessed if they can complete the test. The procedure will be similar to the one described above. If patients cannot complete the visual acuity test, they can still be included in refraction and eye alignment measurements. Instead of the examiner assessing whether the student got the letter correct, the VR device can "hear" the subject call out the letters. The examiner will evaluate whether the device heard it correctly. The VA score will be calculated on what the device heard, after approval from the examiner.

B. Measurement of visual acuity

Starting two lines above the threshold or the last line that failed in the previous test, subjects will read progressively smaller optotypes until they fail. Failure is defined as getting more than two optotypes wrong in a line. A line is passed if at least three optotypes were identified in the line. The visual acuity will be recorded per eye in logMAR units.

C. Measurement of eye alignment

The patient will need to look at an LED light inside the device for eye alignment to be measured. The output of the device will either be No strabismus or With strabismus.

D. Refraction

The refraction will be done one eye at a time. Subjects will have to be still and focus on a red light target in the device for about 5 to 10 seconds per eye.

E. Results

Results of the tests can be seen in an app installed on a smartphone linked to the VR device.

F. Retest

After a few minutes, repeat testing will be done.

Table 4. Eye condition and findings that will flag a person who needs a comprehensive eye exam

Eye Condition	Criteria for flagging
Amblyopia	Visual acuity difference of more than two lines between the two eyes
	Visual acuity worse than 20/30 in either eye
Strabismus	Any measured eye misalignment
Refractive error*	
Hyperopia	> 3.50 (> 1.50 if with strabismus)
Myopia	> 2.50
Astigmatism	> 1.50
Anisometropia	> 1.50

Suspicion of media opacity	No refractive error reading; any note of media opacity grossly

*Measurements are based on Instrument-based screening thresholds for 49 months and above, for dry refraction (AAPOS)

3.5 Data Analysis

3.5.1 Visual acuity

There are two dependently comparable data in the visual acuity test: the actual (clinical) and the experimental (iVRead) values. Since the data is not normally distributed, the Wilcoxon Signed-Ranks test will be used to evaluate the hypothesis. This test is the non-parametric alternative for a paired samples t-test. Wilcoxon Signed-Ranks test uses sample information to assess how plausible it is for population median difference to be equal to zero; if the P-value is less than 0.05 ($P<0.05$), then the null hypothesis is rejected, which means that the means of each sample significantly differ, otherwise, the null hypothesis is accepted.

3.5.2 Hirschberg or corneal light reflex test

For the light reflex test, we will use the paired-samples t-test. The null hypothesis is that the mean difference between the two groups is zero.

3.5.3 Refraction

Comparisons between refractive error measures (the mean difference, standard deviation, and 95% confidence limits) can be calculated using a paired two-tailed t-test.

A confusion matrix is also used to further test the three tests' accuracy. The matrix will contain true positive, true negative, false negatives, and false positives values. False negatives indicate when the device predicts lower values than the actual ones. In comparison, false positives indicate the times the device predicted higher values than the actual values. In other words, the measures that will interpret the confusion matrix are accuracy, misclassification or error rate, miss rate, and fall-out rate. The formulas for computations are shown in Equations 2-5. The values that will be obtained for the spherical, cylindrical, and axial refractive errors will be averaged to assess the device's performance in detecting refractive errors.

$$Accuracy\ \text{rate} = \frac{\Sigma\ \text{True Positive+True Negative}}{\Sigma\ \text{Total Samples}} \tag{2}$$

$$Misclassification\ Rate = 1 - Accuracy\ Rate \tag{3}$$

$$Miss\ Rate = \Sigma\ False\ Negative\ \Sigma\ Condition\ Positive \tag{4}$$

$$Fall{-}out\ Rate = \frac{\Sigma\ \text{False Positive}}{\Sigma\ \text{Condition Negative}} \tag{5}$$

3.6 Evaluation Procedure

To ensure the software quality, identifying and specifying the requirement of the good software quality is vital for it will be the foundation of the desired quality of the final product. The study will employ the ISO/EIC 25010 standard as it provides a list of criteria pursued in this study (see Table 5). It aims to acquire feedback from the field experts such as ophthalmologists and other stakeholders such as parents, electronics engineers, programmers, etc.

3.7 Technical Evaluation

Table 5. Survey Questionnaire using ISO/IEC 25010 Standard

Legend: 5 – Strongly Disagree
4 – Disagree
3 – Neither Agree nor Disagree
2 – Agree
1 – Strongly Agree

<table>
<tr><th colspan="7">Amblyopia Detection for Children Survey</th></tr>
<tr><td colspan="7">Introduction: The students involved prior to this study need to conduct a survey for evaluation of different aspects of the proponent, entitled “ iVRead: INTERACTIVE VIRTUAL REALITY FOR EARLY DETECTION OF AMBLYOPIA FOR KINDERGARTEN PUPILS.”</td></tr>
<tr><td colspan="7">Instruction: Please rate whether you strongly disagree or strongly agree. Check one response of the following statements. Rate 1- if Strongly Disagree 2 – disagree 3 - neither agree nor disagree 4 - agree 5- if Strongly Agree</td></tr>
<tr><td colspan="2" rowspan="2">Survey Statements</td><td colspan="5">Rating</td></tr>
<tr><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td></tr>
<tr><td colspan="7">Functional Suitability</td></tr>
<tr><td>Completeness</td><td>1. The device function according to the specifications.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Correctness</td><td>2. The device provides an accurate result.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Appropriateness</td><td>3. The device fulfills its function.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="7">Performance Efficiency</td></tr>
<tr><td>Time behavior</td><td>1. The vision screening test conducted using the device works faster compared to the traditional test.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Resource utilization</td><td>2. The things are done correctly, minimum time with the minimum cost incurred, and no waste of resources.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="7">Compatibility</td></tr>
<tr><td>Co-existence</td><td>1. The VR and control panel work together without problem or conflict.</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Interoperability	2. The control panel functions with the VR simultaneously.					
Usability						
Appropriateness recognizability	1. The device can be recognized as a tool to detect risk factors of amblyopia.					
Learnability	2. The instructions can be understood easily.					
Operability	3. The controls can be easy to operate.					
User error protection	4. The device protects users against making errors.					
User interface aesthetics	5. The user interface is pleasing to the eye.					
Reliability						
Maturity	1. The device is stable in conducting vision screening.					
Availability	2. The device can be used anytime.					
Fault tolerance	3. The device works even when there are some hardware or software faults.					
Recoverability	4. The data can be recovered in case of system failure					
Security						
Confidentiality	1. The data is accessible only to authorized people.					
Integrity	2. The device prevents unauthorized access to or modification of data.					
Accountability	3. Any alteration in the results is recorded.					
Maintainability						
Analyzability	1. The sequence process of the entire program can be easy to understand.					
Testability	2. The device is automated that can perform three tests, namely visual acuity, ocular motility, and refractive error detection.					

3.8 Implementation Plan

Table 6. Project Implementation Plan

MONTH	ACTIVITIES	PROTOCOL
JUNE	• Coding for 3D animation • Canvassing and Purchasing of Materials	• Canvassing and Purchasing of materials are encouraged via an online platform • If the component is unavailable online, the members who purchase in the physical store **must follow the safety protocols.** • The members are not encouraged to meet in person.
JULY to NOVEMBER	• Raspberry Pi Programming • System Programming • Building the prototype • Coding for Android Application • Development for the Website	• Communication and collaboration between the members are encouraged to be conducted online. • Communication and collaboration between the members are encouraged to be conducted online. • The members must stay in a safe place to build the prototype. • Only members that are assigned to the hardware device are allowed to stay. • **Strict safety health protocols must be implemented**
DECEMBER	• Device Testing	• **Strict safety health protocols must be implemented**

3.9 Work plan (Gantt chart)

Table 7. Project Work Plan

	2021										2022				
ACTIVITIES	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEPT**	**OCT**	**NOV**	**DEC**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**
Topic Consultation															
Research on relevant studies															
Formulation and Submission of Chapter 1 to 3															
Canvassing and Purchasing of Materials for the system															
Coding for the 3D Animation															
Coding for the Android Application															
Developing the Website															
Raspberry Pi Programming															
Coding for the Speech Recognition															

Project Development (Prototype)															
Testing of Refractive Error															
Project Deployment															
Experimentation and Testing															
Formulation of Chapter 4-5															
Finalization of the Thesis Paper															
Demonstration															
Commercialization															

3.9.1 Bill of Materials

Table 8. Bill of Materials

MATERIALS	QUANTITY	PRICE	COST
Collimating Lens	1	Php 500.00	Php 500.00
LED	2	Php 4.00	Php 8.00
Microlens Array	1	Php 32,000.00	Php 32,000.00
Power supply	1	Php 1,800.00	Php 1,800.00
Raspberry Pi 3	2	Php 5,000.00	Php 10,000.00
USB Camera	2	Php 3,000.00	Php 6,000.00
Earphones	1	Php 500.00	Php 500.00
Foam Cartridge	1	Php 200.00	Php 200.00
SD Card	2	Php 500.00	Php 1,000.00
Camera holder	2	Php 240.00	Php 480.00
HDMI to micro–HDMI Cable	1	Php 500.00	Php 500.00
HDMI to HDMI cable	1	Php 65.00	Php 65.00
Insulation Foam	1	Php 1,440.00	Php 1,440.00
Foam Strap	1	Php 100.00	Php 100.00
VR lens	2	Php 120.00	Php 120.00
3D Printing Service	1	Php 42,000.00	Php 42,000.00
		Total	**Php 112,913.00**

CHAPTER 4

RESULTS AND DISCUSSION

This chapter presents the interpretation of gathered data and analysis of the results based on the tests conducted.

4.1 Project Technical Description

The project entitled iVRead: Interactive Virtual Reality for Early Detection of Amblyopia for Kindergarten Pupils is a device that measures refraction and eye alignment and visual acuity. This study aimed to develop an accurate, inexpensive, and simple-to-use vision screening device that will complement the vision screening kit provided by PERI to improve the detection of amblyopia and its risk factors among kindergarten children in the Philippines.

This project utilizes head-mounted virtual reality technology, speech recognition, Shack-Hartmann wavefront sensing, and image processing.

The users will wear the VR while sitting in a chair. The lay screener can start the procedure once the patient is ready. The controls and the results of each test can be seen in the “iVRead controls.” The first test is the visual acuity test, wherein the patient will be asked to read the letters seen on the VR screen. The response will be recorded and identified via speech recognition. The lay screener can check whether the system identified the response correctly or not. Once the VA test is finished, the visual acuity measurement with correction will be displayed. The next test is the light reflex test. In this test, the patient will be asked to look directly at white light, and then the lay screener will capture it, and it will automatically be processed using the horizontal coordinate classification (HCC) algorithm, and the eye alignment will be computed using the CCLR ratio. The result will also be displayed in the app—lastly, the refractive error detection. The patient will be asked to look at the red light one eye at a time. The camera will capture each eye, and the image will be processed to generate the reconstructed Wavefront image. Relevant data will be extracted from the reconstructed wavefront image, which will be used to compute for Zernike Coefficients to obtain the axial, cylindrical, and spherical aberrations of the eyes.

Once the three tests are done, the summary of each test and an overall result will be displayed in the app. If the patient failed at least one of the tests, the device would recommend the patient see an ophthalmologist for further assessment. The results will be uploaded and stored on the website that doctors and authorized personnel can only access.

4.2 Project Structural Organization

4.2.1. VR Device

Figure 18. **Front view of the device**

(a)

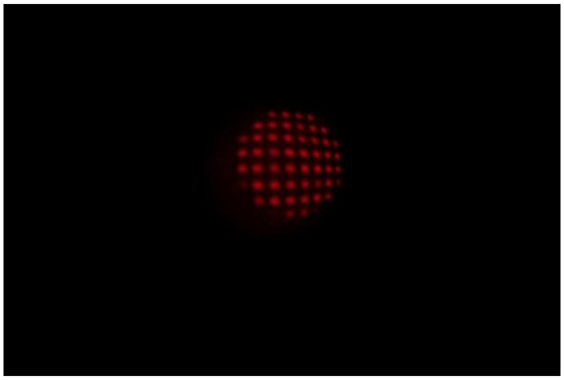
(b)

Figure 19. **Side views of the device** (a) Left side (b) Right side

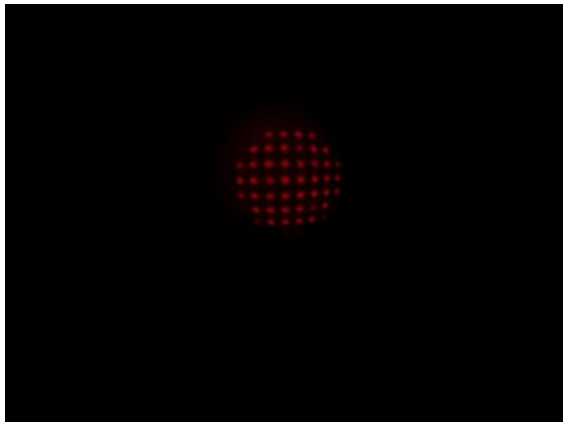
4.2.2 Sample Raw Images

Figure 20. **Sample raw image from light reflex test**

Figure 20 shows the sample raw images taken from the pi camera in light reflex test. This raw image will undergo digital image processing and eye misalignment calculation to detect whether or not the patient has no strabismus.



(a)



(b)

Figure 21. **Sample raw images from wavefront sensor** (a) left eye (b) right eye

Figure 21 shows the sample raw images that were obtained from the wavefront sensor. This raw image contains spots containing data that will be used to measure the refractive error. Algorithms will process the data from the image to obtain the desired output.

4.2.3 iVRead Controls

Figure 22.a Main Window

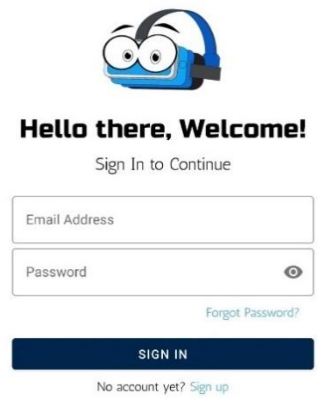


Figure 22.b Login Page

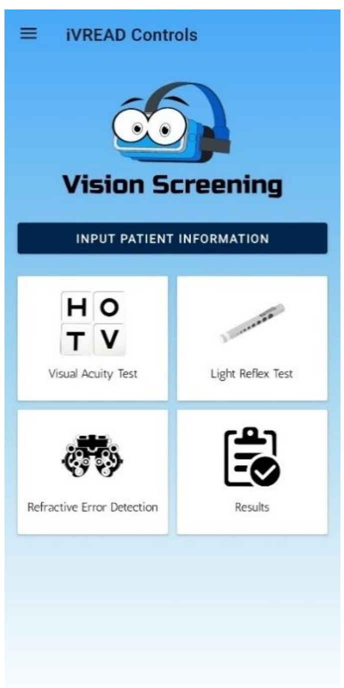


Figure 22.c Main dashboard

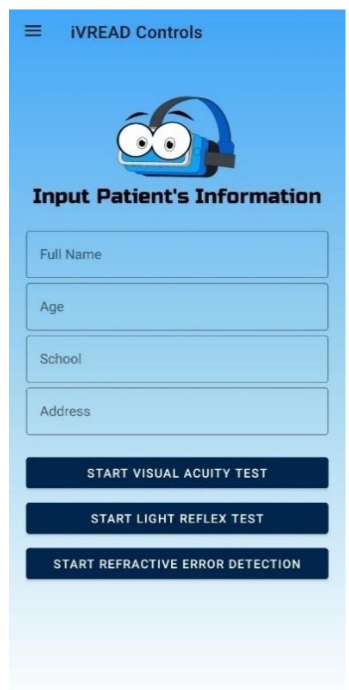


Figure 22.d Patient's Information Page

Figure 22.e Visual acuity test start page

Figure 22.f Visual acuity test lines

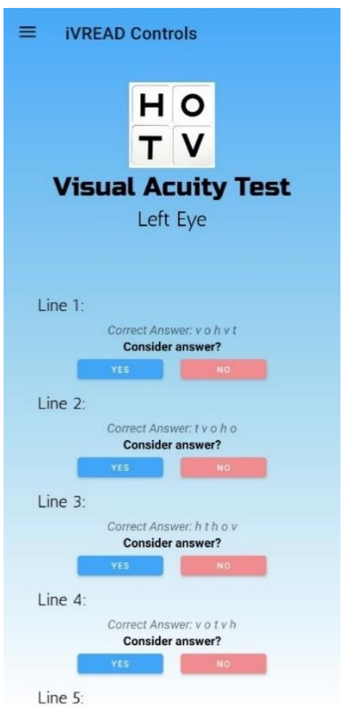


Figure 22.g.1 Visual acuity test response confirmation

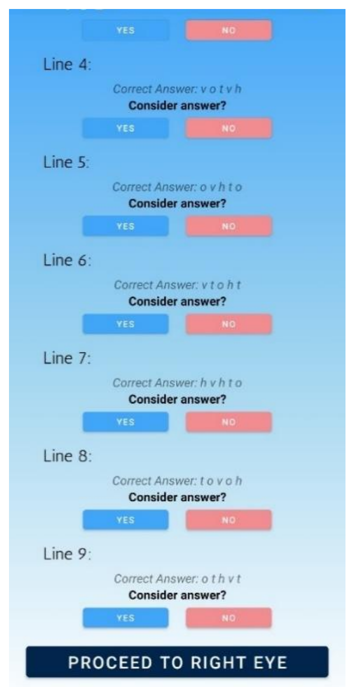


Figure 22.g.2 Visual acuity test response confirmation

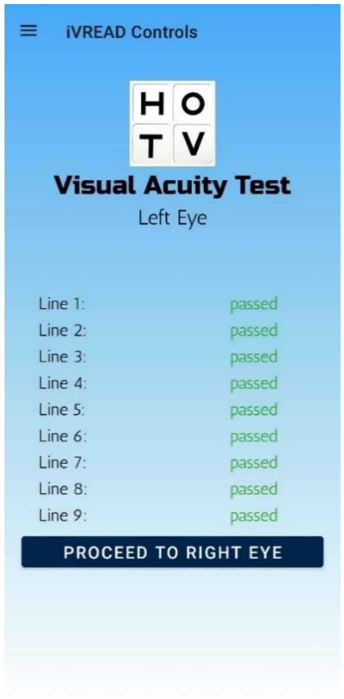


Figure 22.g.3 Visual acuity test response confirmation

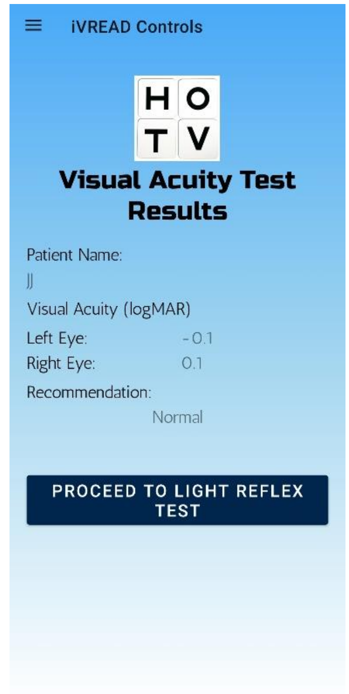


Figure 22.h Visual acuity test results

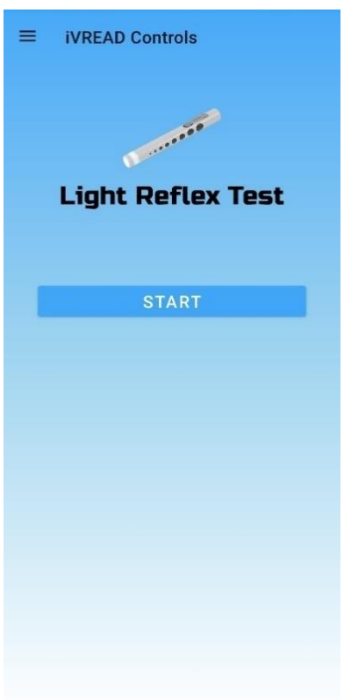


Figure 22.i Light reflex test start button

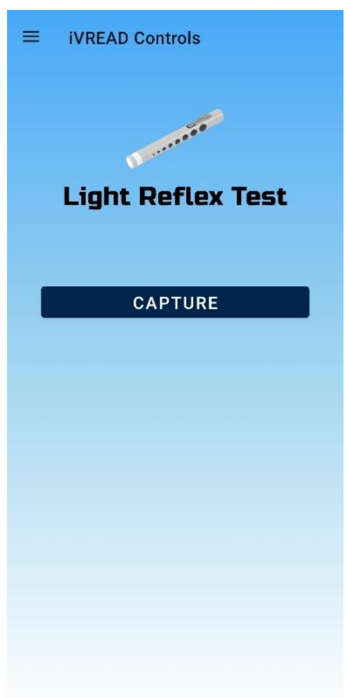


Figure 22.j Light reflex test capture button

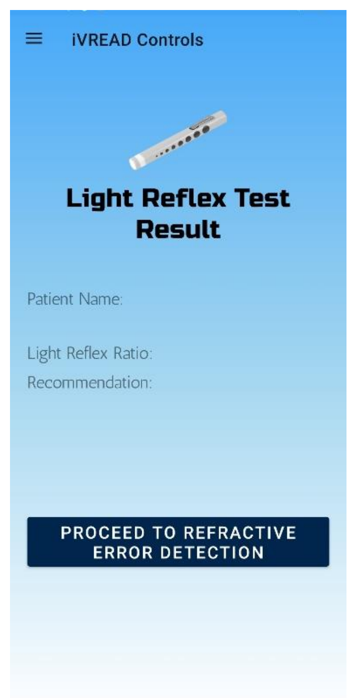


Figure 22.k Light reflex test results

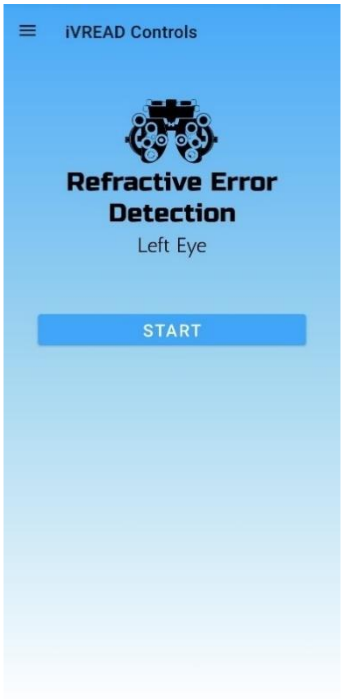


Figure 22.l Refractive error detection start button on left eye

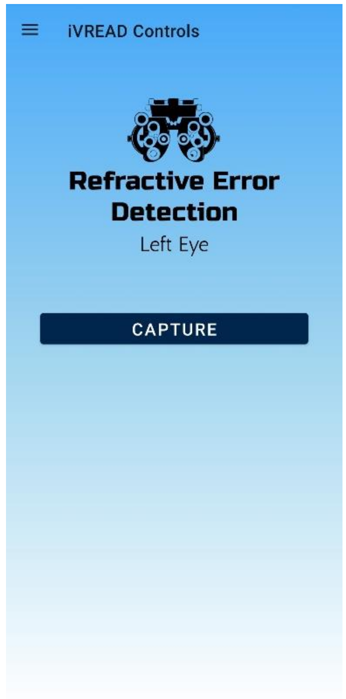


Figure 22.m Refractive error detection capture button on left eye

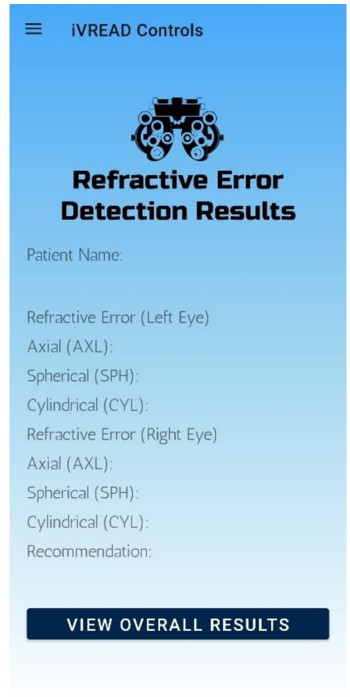


Figure 22.n Refractive error detection results

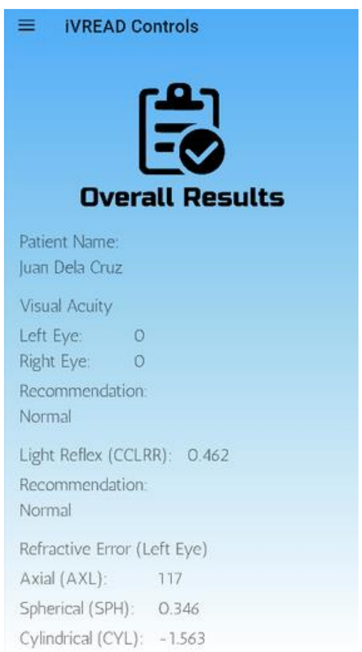


Figure 22.o1 Overall Results

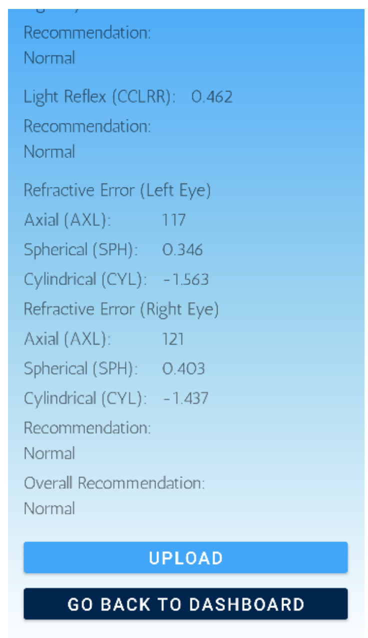


Figure 22.o2 Overall Results

Figure 22. **iVRead controls GUI**

Figure 22.a shows the main window of the iVRead app. To access the app, login credentials are needed (see Figure 22.b). To be able to have an account, the user must sign up first. The account can also be logged on to the website to view the record lists. Figure 22.c displays the app's main dashboard, and Figure 22.d shows the input panel for patient information. After that, the examiner may start the visual acuity test once the patient is ready. This test is done monocularly (one eye at a time). The HOTV chart is displayed line-per-line as shown in the controls of Figure 22.f. The voice processing system will automatically identify the letters the patient has read. At the end of the test, the examiner may check whether the system identified the inputs correctly or not (See Figure 22.g). Finally, the visual acuity test results will be displayed (see Figure 22.h). The results are composed of the patient’s name, visual acuity measurement for the left and right eye, and the recommendation of whether the patient has normal VA or has a VA with correction.

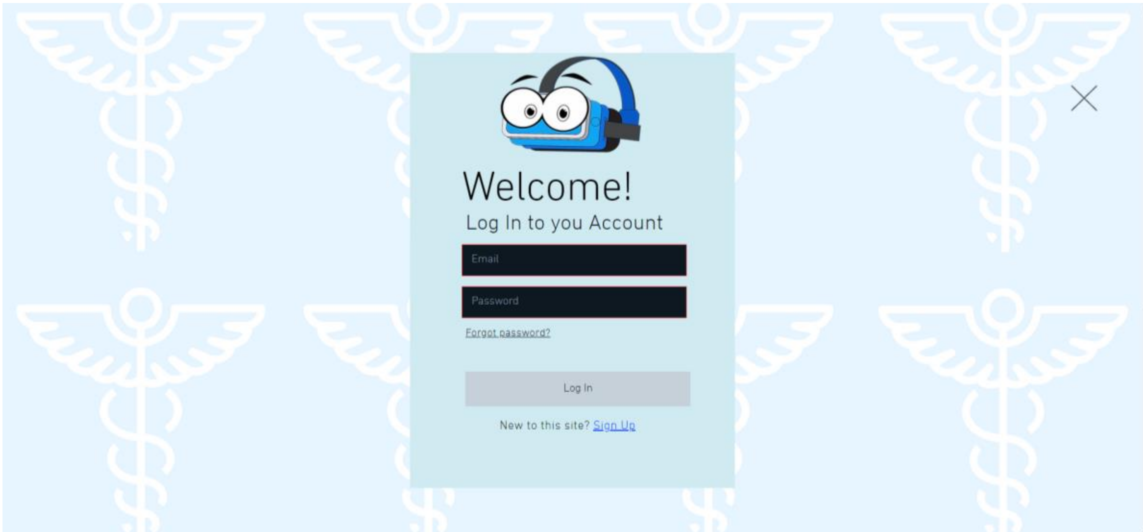
Figures 22.i-k shows the controls for the light reflex test. This test is done binocularly, meaning two eyes at a time. The patient will be asked to look at a white light for a moment. Once the image of the eyes is captured, the image processing and data calculation will automatically take place, thus will provide the desired result. The results are composed of the patient's name, CCLR ratio or light reflex ratio, and a recommendation if the patient has No Strabismus or With Strabismus.

The next and last test is the refractive error detection shown in Figures 22.l-n. The patient will be asked to look at a red LED one eye at a time. Once the images are captured, the results for both eyes will be displayed. The results are composed of the patient's name, refraction measurement (SPH, CYL, and AXL), and the recommendation of whether the patient has normal vision or has a refractive error.

Figures 22.o shows the summary of the results from the three tests. If the patient failed at least one of the exams, the device would recommend the patient to see a Pediatric Ophthalmologist for further assessment. These results will be uploaded to the website in real-time.

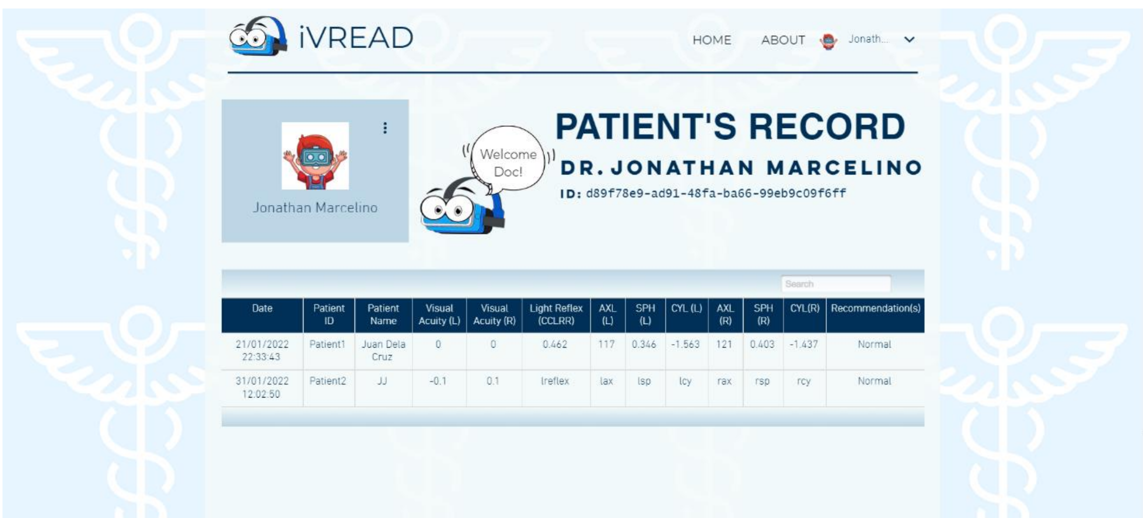
4.2.4 Website

(a)



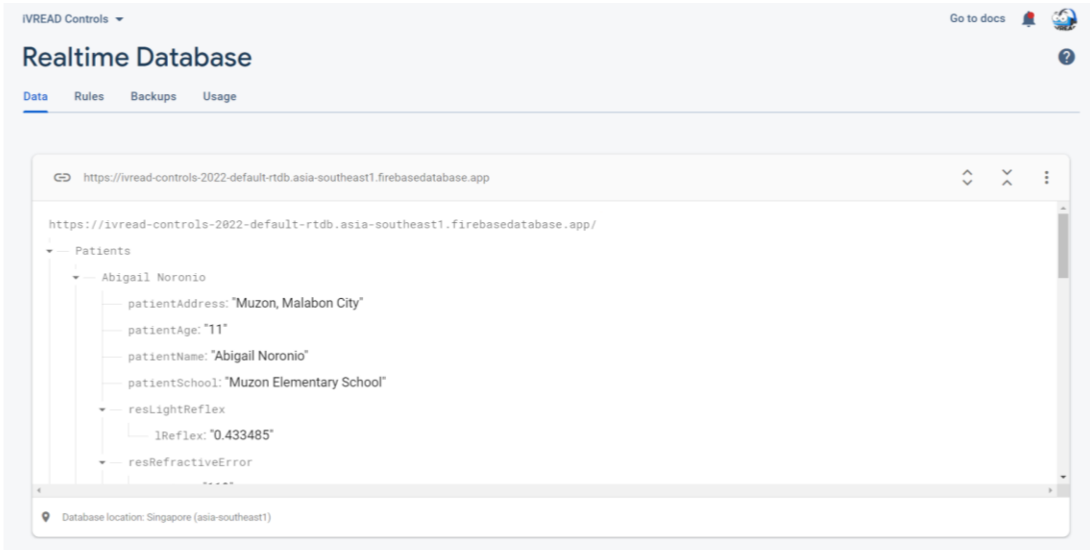
Welcome!
Log In to you Account
Email
Password
Forgot password?
Log In
New to this site? Sign Up

(b)



iVREAD
HOME
ABOUT
PATIENT'S RECORD
DR. JONATHAN MARCELINO
ID: d89f78e9-ad91-48fa-ba66-99eb9c09f6ff
Welcome Doc!
Jonathan Marcelino
Search
Date | Patient ID | Patient Name | Visual Acuity (L) | Visual Acuity (R) | Light Reflex (CCLRR) | AXL (L) | SPH (L) | CYL (L) | AXL (R) | SPH (R) | CYL (R) | Recommendation(s)
21/01/2022 22:33:43 | Patient1 | Juan Dela Cruz | 0 | 0 | 0.462 | 117 | 0.346 | -1.563 | 121 | 0.403 | -1.437 | Normal
31/01/2022 12:02:50 | Patient2 | JJ | -0.1 | 0.1 | lreflex | lax | lsp | lcy | rax | rsp | rcy | Normal

(c)



(d)

Figure 23. **Website GUI** (a) Main window (b) Login Page (c) Patient's Record (d) Firebase

Figures 23.a-c show the interfaces of the website. Figure 23.b shows the website's login page that can be accessed by the operating ophthalmologist or authorized personnel only. The overall result of eachPatient is uploaded and stored on the website in real-time.

4.3 Project Limitations and Capabilities

This study focuses on constructing a device that utilizes head-mounted virtual reality technology to accurately measure refraction, eye alignment, and visual acuity to detect amblyopia and its risk factors in children 5–6-year-old.

This study utilizes speech recognition, Shack-Hartmann wavefront sensing, image processing, and algorithms such as Zernike polynomial, Fast Fourier Transform, and Horizontal Coordinate Classification algorithm. The results of each test will be displayed on the iVRead app and will be reflected on the website. The device will recommend whether a patient is at risk of amblyopia. The device will not diagnose a patient. This will serve as an accurate initial screening to identify children who need a referral to eye care specialists for treatment.

4.4 Experimental Results and Data Analysis

The measurements obtained in the VR device were compared to traditional eye exams performed by a pediatric ophthalmologist and a clinical auto refractometer. The iVRead device is validated and tested at Manila Doctors Hospital located at Ermita, Manila, supervised by the Director of PERI, Dr. Leo Cubillan, and his Assistant Director and a Medical Optics Physicist, Dr. Arni Sicam. Our clinical study adviser, Dr. Patricia Cabrera, a pediatric ophthalmologist in UP-PGH, arranged the testing.

Aside from Manila Doctors Hospital, we also gather data in a private optical clinic in Malabon. The participants' age ranges from 10 to 27 years old. The following table shows the data gathered in the three vision screening tests. With a total of 15 test subjects, proponents obtained 30 samples, one sample in each of the subjects, in the visual acuity test and refractive error detection and 15 samples for light reflex test.

Figure 24. **Pilot Testing**

Figure 25. **Results obtained from the device**

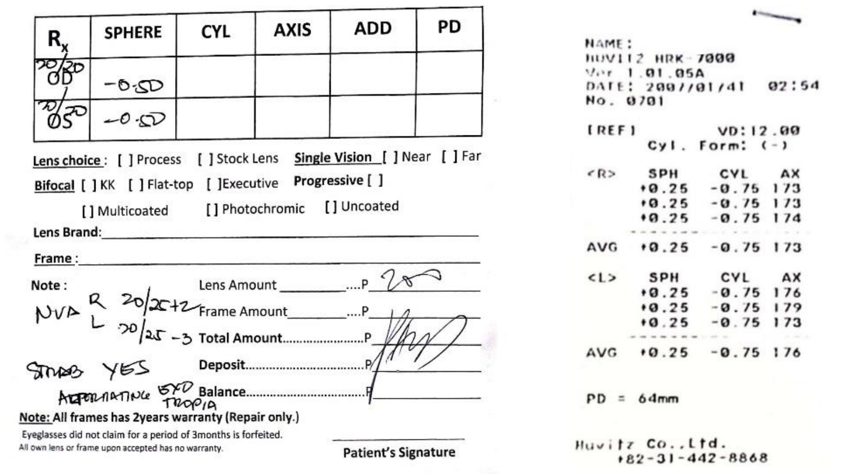


Figure 26. **Results obtained from the traditional vision screening and an autorefractor**

The data obtained in the three tests undergo different hypothesis testing and confusion matrix. The data is analyzed using the Wilcoxon signed-rank test in the visual acuity test.

Sample 1	iVRead
Sample 2	Clinical

	Sample 1	Sample 2
Sample size	30	30
Lowest value	0.0000	0.0000
Highest value	1.5000	1.6000
Median	0.1000	0.1000
95% CI for the median	0.01750 to 0.2000	0.1000 to 0.2000
Interquartile range	0.0000 to 0.6000	0.0000 to 0.7000

Hodges-Lehmann median difference	0.0000
95% Confidence interval	0.0000 to 0.05000

Wilcoxon test (paired samples)

Number of positive differences	7
Number of negative differences	2
Large sample test statistic Z	-1.836282
Two-tailed probability	P = 0.0663

Figure 27. **Summary of Wilcoxon signed-rank test**

In summary, as shown in figure 27, the two-tailed probability (P) is 0.0663, and it is greater than the significance level of 0.05, which means that we have to accept the null hypothesis. The median of the population of the paired differences is zero. This implies that the visual acuity test using iVRead is accurate and acceptable.

In the light reflex test (LRT), the data were analyzed using paired samples t-test. Using the P-value approach, the p-value is 0.1643, and since p is more significant than 0.05 (significance level), it is concluded that the null hypothesis is not rejected. Therefore, the mean difference between iVRead and Clinical results is zero.

Table 9. Summary of paired t-test results in LRT

	iVRead	*Manual*
Mean	0.266666667	0.13333333
Variance	0.20952381	0.12380952
Observations	15	15
Pearson Correlation	0.650443636	
Hypothesized Mean Difference	0	
df	14	
t Stat	1.467598771	
P(T<=t) one-tail	0.082158949	
t Critical one-tail	1.761310136	
P(T<=t) two-tail	**0.164317898**	
t Critical two-tail	2.144786688	

Moreover, in the refractive error detection (RED), paired sample t-test is used to compare the results from the clinical autorefractor from the iVRead device.

Table 10. Summary of Paired samples t-test in RED

	SPH		**CYL**		**AX**	
	iVRead	***Autorefractor***	***iVRead***	***Autorefractor***	***iVRead***	***Autorefractor***
Mean	-1.416666667	-1.041666667	-1.225	-1.283333333	81.43333333	76.76666667
Variance	1.92816092	3.694324713	0.988577586	1.067816092	3808.667816	5870.667816
Observations	30	30	30	30	30	30
Pearson Correlation	0.530258721		0.978333558		0.833378053	
Hypothesized Mean Difference	0		0		0	
df	29		29		29	
t Stat	-1.229227243		1.488908551		0.602806765	
P(T<=t) one-tail	0.114433745		0.073653433		0.2756613	
t Critical one-tail	1.699127027		1.699127027		1.699127027	
P(T<=t) two-tail	**0.228867491**		**0.147306866**		**0.5513226**	
t Critical two-tail	2.045229642		2.045229642		2.045229642	

The p-values of SPH, CYL and AX are 0.2289, 0.1473, and 0.5513, respectively. Since the following p-values are all greater than the significance value of 0.05, this proves that the population mean difference is zero. Thus, there is no significant difference between the iVRead results and autorefractor results.

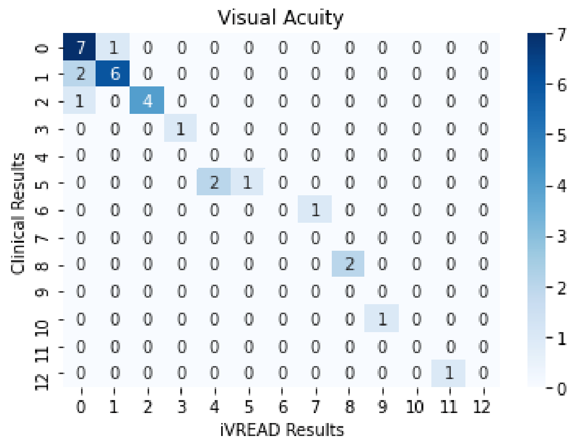


Figure 28. **Confusion matrix of VAT**

Table 11. Confusion Matrix Analysis of VAT

Measure	Calculated values
Accuracy	0.7
Misclassification Rate	0.3
Miss Rate	0.32
Fall-out	0.05

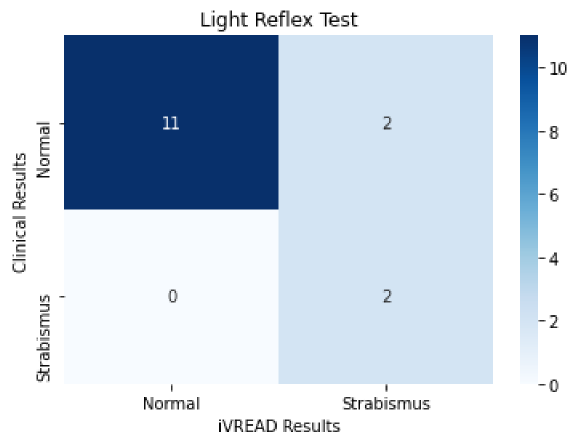
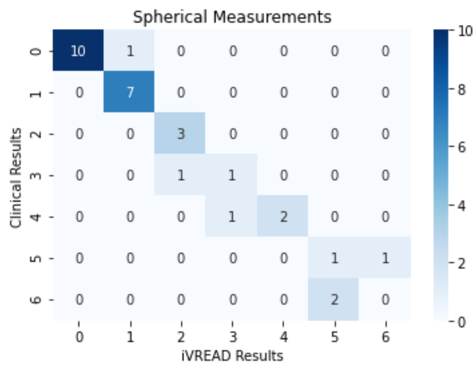


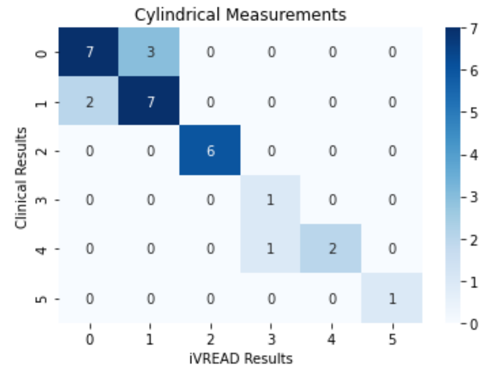
Figure 29. **Confusion matrix of LRT**

Table 12. Confusion Matrix Analysis of LRT

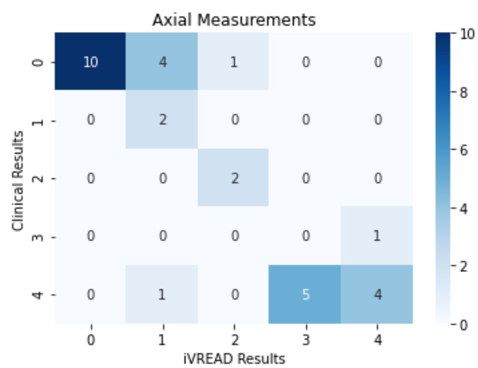
Measure	Calculated values
Accuracy	0.87
Misclassification Rate	0.13
Miss Rate	0
Fall-out	0.15



(a)



(b)



(c)

Figure 30. **Confusion matrix of RED** (a) Spherical measurements (b) Cylindrical measurements (c) Axial measurements

Table 13. Confusion Matrix Analysis of SPH measurement

Measure	Calculated values
Accuracy	0.8
Misclassification Rate	0.2
Miss Rate	0.17
Fall-out	0.08

Table 14. Confusion Matrix Analysis of CYL measurement

Measure	Calculated values
Accuracy	0.8
Misclassification Rate	0.2
Miss Rate	0.13
Fall-out	0.13

Table 15. Confusion Matrix Analysis of AX measurement

Measure	Calculated values
Accuracy	0.6
Misclassification Rate	0.4
Miss Rate	0.3
Fall-out	0.3

Table 16. Summary of confusion Matrix Analysis of RED

Measure	Calculated values
Accuracy	0.73
Misclassification Rate	0.27
Miss Rate	0.2
Fall-out	0.17

Based on the confusion matrix analysis, the refractive error detection accuracy is about 0.7333 or 73.33%, and the misclassification or error rate is about 0.2667 or 26.67%. Overall, the accuracy of the VR device is 0.7667 or 76.67%, and the misclassification rate is 0.2322 or 23.22%. This means that, on average, the device accurately assessed the refractive errors of 23 out of 30 samples. The average miss rate is 0.1733 or 17.33%, and the average fall-out rate is 0.1233 or 12.33%. Feedback from the users and supervising doctors were also obtained through a survey. Figure 31 shows the survey results in line with the ISO/IEC 20510 standard.

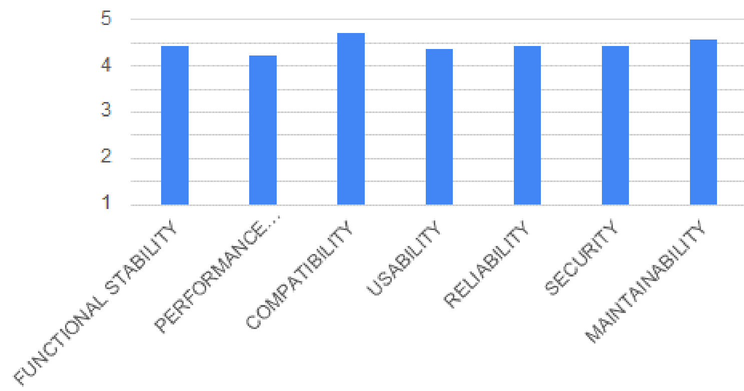


Figure 31. **Summary of survey results**

The evaluation of the accuracy and performance of the device proves that the iVRead developed in this study was able to deliver good results that may serve as an aid for complementing the vision screening kit provided by PERI to improve the detection of amblyopia risk factors.

CHAPTER 5

SUMMARY OF FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

5.1 Summary of Findings

iVRead device provides accurate results in obtaining the visual acuity, presence of strabismus, and measuring the eye's aberration. Based on the hypothesis testing, the device is said to be effective since all the null hypotheses are accepted. In addition, the device garnered an overall accuracy percentage of 76.67%, and the misclassification rate was 0.2322 or 23.22%. This means that, on average, the device accurately assessed the refractive errors of 23 out of 30 samples. The average miss rate is 0.1733 or 17.33%, and the average fall-out rate is 0.1233 or 12.33%. Therefore, the prototype accurately detects amblyopia risk factors and is an acceptable tool for vision screening. Some factors that will affect the testing are underlying eye health conditions, testing environment, and patient age. According to ophthalmologists, the eyes of the children are very flexible. They can have worse refractive error but can have a 20/20 vision at the same time. One way to prevent that from happening during testing is for doctors to apply cycloplegic eye drops in the eyes of the patient, which temporarily paralyzes the ciliary body, allowing a doctor to measure a patient's vision problem fully. When the ciliary body is paralyzed, the eye cannot focus on near or intermediate objects.

5.2 Conclusions

1. The proponents have been able to design and develop a device utilizing Virtual Reality technology that will perform visual acuity test, light reflex test, and

refractive error detection. The researchers acquired materials from different countries, considering the cost and quality of each material and component. The case of the device is 3D printed and manually designed to reach the needed specifications and dimensions of the sensor to produce quality data.

2. The proponents have been able to develop a 3D software animation, an android application that controls the device's functionality, and a website that will consolidate and store the vision screening results.
3. The devised algorithm in this study uses a speech recognition algorithm to measure visual acuity, the Hough and Blob algorithm to detect the presence of strabismus, and Zernike Polynomials and Fast Fourier Transform to detect the aberration of the eyes. With this, the device can detect amblyopia risk factors in patients and recommend them to see an Ophthalmologist.
4. The device is an accurate and acceptable tool to detect amblyopia risk factors such as visual acuity, refractive error, and eye misalignment. It is also portable and easy to use. Hence it can be used by lay screeners.

With the use of the device, early detection of amblyopia risk factors in children is essential. An immediate correction using contact lenses, eyeglasses, or refractive surgeries will prevent further complications. Also, the device is portable and affordable compared to the commercially available VR devices that conduct vision screening tests which can be useful for practitioners to have an initial testing result.

5.3 Recommendations

To further improve the study, researchers recommend reconsidering the distance of the visual acuity chart and considering if the contrast and lighting in the VR app can affect the patient's reading. Apply Shack-Hartmann sensor to determine strabismus with tilt aberration component in the wavefront. With regards to the VR design, the proponents suggest to device a more compact form and make some windows in the light reflex test setup for the subjects' eyes stare farther, and the iris will not seem to look as if it has strabismus.

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APPENDIX A

Needs Assesment

The proponents employs ISO/IEC 25010 standard for the evaluation of the device. It has 20 questions composed of rating for functional suitability, performance efficiency, compatibility, usability, reliability, security, and maintainability. The purpose of this survey is to evaluate the device using the ISO/IEC 25010 standard.

TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES
Ayala Blvd., Ermita, Manila, 1000, Philippines
Tel. No. +632-301-3001 | Fax No. +632-521-4063
Email: tup@tup.edu.ph | Website: www.tup.edu.ph

QUESTIONNAIRE

The students involved prior to this study need to conduct a survey for evaluation of different aspects of the proponent, entitled "*VRead: INTERACTIVE VIRTUAL REALITY FOR EARLY DETECTION OF AMBLYOPIA FOR KINDERGARTEN PUPILS.*"

Instruction: Please rate whether you strongly disagree or strongly agree. Check one response of the following statements. Rate 1 - if strongly disagree 2 – disagree 3 - neither agree nor disagree 4 - agree 5 - if strongly agree

Name: ____________________ Occupation: ____________ Date: ____

(Optional)

	SURVEY STATEMENTS	Rating 5	4	3	2	1
FUNCTIONAL SUITABILITY						
Completeness	1. The device function according to the specifications.					
Correctness	2. The device provides an accurate result.					
Appropriateness	3. The device fulfills its function.					
PERFORMANCE EFFICIENCY						
Time behavior	1. The vision screening test conducted using the device works faster compared to the traditional test.					
Resource utilization	2. The things are done correctly, minimum time with the minimum cost incurred, and no waste of resources.					
COMPATIBILITY						
Co-existence	1. The VR and control panel work together without problem or conflict.					
Interoperability	2. The control panel functions with the VR simultaneously.					
USABILITY						
Appropriateness recognizability	1. The device can be recognized as a tool to detect risk factors of amblyopia.					
Learnability	2. The instructions can be understood easily.					
Operability	3. The controls can be easy to operate.					
User error protection	4. The device protects users against making errors.					
User interface aesthetics	5. The user interface is pleasing to the eye.					
RELIABILITY						
Maturity	1. The device is stable in conducting vision screening.					
Availability	2. The device can be used anytime.					
Fault tolerance	3. The device works even when there are some hardware or software faults.					
Recoverability	4. The data can be recovered in case of system failure					
SECURITY						
Confidentiality	1. The data is accessible only to authorized people.					
Integrity	2. The device prevents unauthorized access to or modification of data.					
Accountability	3. Any alteration in the results is recorded.					
MAINTAINABILITY						
Analyzability	1. The sequence process of the entire program can be easy to understand.					
Testability	2. The device is automated that can perform three tests, namely visual acuity, ocular motility, and refractive error detection.					

Figure 32. **Survey Form using ISO/IEC Standard**

TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES
Ayala Blvd., Ermita, Manila, 1000, Philippines
Tel. No. +632-301-3001 | Fax No. +632-521-4063
Email: tup@tup.edu.ph | Website: www.tup.edu.ph

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Name: ______________________ (Optional) Occupation: Mother Date: _

SURVEY STATEMENTS		Rating				
		5	4	3	2	1
FUNCTIONAL SUITABILITY						
Completeness	1. The device function according to the specifications.		✓			
Correctness	2. The device provides an accurate result.	✓				
Appropriateness	3. The device fulfils its function.		✓			
PERFORMANCE EFFICIENCY						
Time behavior	1. The vision screening test conducted using the device works faster compared to the traditional test.		✓			
Resource utilization	2. The things are done correctly, minimum time with the minimum cost incurred, and no waste of resources.		✓			
COMPATIBILITY						
Co-existence	1. The VR and control panel work together without problem or conflict.		✓			
Interoperability	2. The control panel functions with the VR simultaneously.	✓				
USABILITY						
Appropriateness recognizability	1. The device can be recognized as a tool to detect risk factors of amblyopia.		✓			
Learnability	2. The instructions can be understood easily.	✓				
Operability	3. The controls can be easy to operate.		✓			
User error protection	4. The device protects users against making errors.	✓				
User interface aesthetics	5. The user interface is pleasing to the eye.	✓				
RELIABILITY						
Maturity	1. The device is stable in conducting vision screening.		✓			
Availability	2. The device can be used anytime.		✓			
Fault tolerance	3. The device works even when there are some hardware or software faults.		✓			
Recoverability	4. The data can be recovered in case of system failure		✓			
SECURITY						
Confidentiality	1. The data is accessible only to authorized people.		✓			
Integrity	2. The device prevents unauthorized access to or modification of data.		✓			
Accountability	3. Any alteration in the results is recorded.		✓			
MAINTAINABILITY						
Analyzability	1. The sequence process of the entire program can be easy to understand.		✓			
Testability	2. The device is automated that can perform three tests, namely visual acuity, ocular motility, and refractive error detection.		✓			

TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES
Ayala Blvd., Ermita, Manila, 1000, Philippines
Tel. No. +632-301-3001 | Fax No. +632-521-4063
Email: tup@tup.edu.ph | Website: www.tup.edu.ph

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Name: ______________________ (Optional) Occupation: Aunt Date: ______

SURVEY STATEMENTS		Rating 5	4	3	2	1
FUNCTIONAL SUITABILITY						
Completeness	1. The device function according to the specifications.			✓		
Correctness	2. The device provides an accurate result.			✓		
Appropriateness	3. The device fulfils its function.	✓				
PERFORMANCE EFFICIENCY						
Time behavior	1. The vision screening test conducted using the device works faster compared to the traditional test.			✓		
Resource utilization	2. The things are done correctly, minimum time with the minimum cost incurred, and no waste of resources.			✓		
COMPATIBILITY						
Co-existence	1. The VR and control panel work together without problem or conflict.			✓		
Interoperability	2. The control panel functions with the VR simultaneously.			✓		
USABILITY						
Appropriateness recognizability	1. The device can be recognized as a tool to detect risk factors of amblyopia.			✓		
Learnability	2. The instructions can be understood easily.			✓		
Operability	3. The controls can be easy to operate.			✓		
User error protection	4. The device protects users against making errors.			✓		
User interface aesthetics	5. The user interface is pleasing to the eye.			✓		
RELIABILITY						
Maturity	1. The device is stable in conducting vision screening.			✓		
Availability	2. The device can be used anytime.			✓		
Fault tolerance	3. The device works even when there are some hardware or software faults.		✓			
Recoverability	4. The data can be recovered in case of system failure			✓		
SECURITY						
Confidentiality	1. The data is accessible only to authorized people.			✓		
Integrity	2. The device prevents unauthorized access to or modification of data.		✓			
Accountability	3. Any alteration in the results is recorded.			✓		
MAINTAINABILITY						
Analyzability	1. The sequence process of the entire program can be easy to understand.			✓		
Testability	2. The device is automated that can perform three tests, namely visual acuity, ocular motility, and refractive error detection.			✓		

TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES

Ayala Blvd., Ermita, Manila, 1000, Philippines
Tel. No. +632-301-3001 | Fax No. +632-521-4063
Email: tup@tup.edu.ph | Website: www.tup.edu.ph

QUESTIONNAIRE

The students involved prior to this study need to conduct a survey for evaluation of different aspects of the proponent, entitled *"VRead: INTERACTIVE VIRTUAL REALITY FOR EARLY DETECTION OF AMBLYOPIA FOR KINDERGARTEN PUPILS."*

Instruction: Please rate whether you strongly disagree or strongly agree. Check one response of the following statements. Rate 1 - if strongly disagree 2 – disagree 3 - neither agree nor disagree 4 - agree 5 - if strongly agree

Name: ______________________ (Optional) Occupation: Student Date: ________

SURVEY STATEMENTS		Rating				
		5	4	3	2	1
FUNCTIONAL SUITABILITY						
Completeness	1. The device function according to the specifications.	✓				
Correctness	2. The device provides an accurate result.	✓				
Appropriateness	3. The device fulfils its function.		✓			
PERFORMANCE EFFICIENCY						
Time behavior	1. The vision screening test conducted using the device works faster compared to the traditional test.	✓				
Resource utilization	2. The things are done correctly, minimum time with the minimum cost incurred, and no waste of resources.		✓			
COMPATIBILITY						
Co-existence	1. The VR and control panel work together without problem or conflict.	✓				
Interoperability	2. The control panel functions with the VR simultaneously.	✓				
USABILITY						
Appropriateness recognizability	1. The device can be recognized as a tool to detect risk factors of amblyopia.	✓				
Learnability	2. The instructions can be understood easily.	✓				
Operability	3. The controls can be easy to operate.		✓			
User error protection	4. The device protects users against making errors.		✓			
User interface aesthetics	5. The user interface is pleasing to the eye.	✓				
RELIABILITY						
Maturity	1. The device is stable in conducting vision screening.	✓				
Availability	2. The device can be used anytime.	✓				
Fault tolerance	3. The device works even when there are some hardware or software faults.		✓			
Recoverability	4. The data can be recovered in case of system failure	✓				
SECURITY						
Confidentiality	1. The data is accessible only to authorized people.	✓				
Integrity	2. The device prevents unauthorized access to or modification of data.	✓				
Accountability	3. Any alteration in the results is recorded.		✓			
MAINTAINABILITY						
Analyzability	1. The sequence process of the entire program can be easy to understand.	✓				
Testability	2. The device is automated that can perform three tests, namely visual acuity, ocular motility, and refractive error detection.		✓			

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Instruction: Please rate whether you strongly disagree or strongly agree. Check one response of the following statements. Rate 1 - if strongly disagree 2 – disagree 3 - neither agree nor disagree 4 - agree 5 - if strongly agree

Name: ______________________ (Optional) Occupation: Student Date: ________

SURVEY STATEMENTS		Rating				
		5	4	3	2	1
FUNCTIONAL SUITABILITY						
Completeness	1. The device function according to the specifications.	✓				
Correctness	2. The device provides an accurate result.	✓				
Appropriateness	3. The device fulfils its function.		✓			
PERFORMANCE EFFICIENCY						
Time behavior	1. The vision screening test conducted using the device works faster compared to the traditional test.	✓				
Resource utilization	2. The things are done correctly, minimum time with the minimum cost incurred, and no waste of resources.	✓				
COMPATIBILITY						
Co-existence	1. The VR and control panel work together without problem or conflict.	✓				
Interoperability	2. The control panel functions with the VR simultaneously.	✓				
USABILITY						
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Confidentiality	1. The data is accessible only to authorized people.	✓				
Integrity	2. The device prevents unauthorized access to or modification of data.	✓				
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Instruction: Please rate whether you strongly disagree or strongly agree. Check one response of the following statements. Rate 1 - if strongly disagree 2 – disagree 3 - neither agree nor disagree 4 - agree 5 - if strongly agree

Name: ______________________ (Optional) Occupation: Senior Citizen Date: ________

SURVEY STATEMENTS		Rating				
		5	4	3	2	1
FUNCTIONAL SUITABILITY						
Completeness	1. The device function according to the specifications.	✓				
Correctness	2. The device provides an accurate result.	✓				
Appropriateness	3. The device fulfils its function.	✓				
PERFORMANCE EFFICIENCY						
Time behavior	1. The vision screening test conducted using the device works faster compared to the traditional test.		✓			
Resource utilization	2. The things are done correctly, minimum time with the minimum cost incurred, and no waste of resources.	✓				
COMPATIBILITY						
Co-existence	1. The VR and control panel work together without problem or conflict.		✓			
Interoperability	2. The control panel functions with the VR simultaneously.	✓				
USABILITY						
Appropriateness recognizability	1. The device can be recognized as a tool to detect risk factors of amblyopia.		✓			
Learnability	2. The instructions can be understood easily.	✓				
Operability	3. The controls can be easy to operate.	✓				
User error protection	4. The device protects users against making errors.	✓				
User interface aesthetics	5. The user interface is pleasing to the eye.	✓				
RELIABILITY						
Maturity	1. The device is stable in conducting vision screening.		✓			
Availability	2. The device can be used anytime.	✓				
Fault tolerance	3. The device works even when there are some hardware or software faults.		✓			
Recoverability	4. The data can be recovered in case of system failure	✓				
SECURITY						
Confidentiality	1. The data is accessible only to authorized people.	✓				
Integrity	2. The device prevents unauthorized access to or modification of data.		✓			
Accountability	3. Any alteration in the results is recorded.	✓				
MAINTAINABILITY						
Analyzability	1. The sequence process of the entire program can be easy to understand.	✓				
Testability	2. The device is automated that can perform three tests, namely visual acuity, ocular motility, and refractive error detection.	✓				

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Instruction: Please rate whether you strongly disagree or strongly agree. Check one response of the following statements. Rate 1 - if strongly disagree 2 – disagree 3 - neither agree nor disagree 4 - agree 5 - if strongly agree

Name: ______________________ (Optional) Occupation: Data Analyst Date: ________

SURVEY STATEMENTS		Rating				
		5	4	3	2	1
FUNCTIONAL SUITABILITY						
Completeness	1. The device function according to the specifications.	✓				
Correctness	2. The device provides an accurate result.		✓			
Appropriateness	3. The device fulfils its function.		✓			
PERFORMANCE EFFICIENCY						
Time behavior	1. The vision screening test conducted using the device works faster compared to the traditional test.	✓				
Resource utilization	2. The things are done correctly, minimum time with the minimum cost incurred, and no waste of resources.	✓				
COMPATIBILITY						
Co-existence	1. The VR and control panel work together without problem or conflict.	✓				
Interoperability	2. The control panel functions with the VR simultaneously.	✓				
USABILITY						
Appropriateness recognizability	1. The device can be recognized as a tool to detect risk factors of amblyopia.		✓			
Learnability	2. The instructions can be understood easily.	✓				
Operability	3. The controls can be easy to operate.	✓				
User error protection	4. The device protects users against making errors.		✓			
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RELIABILITY						
Maturity	1. The device is stable in conducting vision screening.		✓			
Availability	2. The device can be used anytime.	✓				
Fault tolerance	3. The device works even when there are some hardware or software faults.		✓			
Recoverability	4. The data can be recovered in case of system failure		✓			
SECURITY						
Confidentiality	1. The data is accessible only to authorized people.	✓				
Integrity	2. The device prevents unauthorized access to or modification of data.	✓				
Accountability	3. Any alteration in the results is recorded.	✓				
MAINTAINABILITY						
Analyzability	1. The sequence process of the entire program can be easy to understand.	✓				
Testability	2. The device is automated that can perform three tests, namely visual acuity, ocular motility, and refractive error detection.	✓				

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Instruction: Please rate whether you strongly disagree or strongly agree. Check one response of the following statements. Rate 1 - if strongly disagree 2 – disagree 3 - neither agree nor disagree 4 - agree 5 - if strongly agree

Name: ______________________ Occupation: Student Date: ________
(Optional)

SURVEY STATEMENTS		Rating				
		5	4	3	2	1
FUNCTIONAL SUITABILITY						
Completeness	1. The device function according to the specifications.	✓				
Correctness	2. The device provides an accurate result.	✓				
Appropriateness	3. The device fulfils its function.	✓				
PERFORMANCE EFFICIENCY						
Time behavior	1. The vision screening test conducted using the device works faster compared to the traditional test.		✓			
Resource utilization	2. The things are done correctly, minimum time with the minimum cost incurred, and no waste of resources.		✓			
COMPATIBILITY						
Co-existence	1. The VR and control panel work together without problem or conflict.	✓				
Interoperability	2. The control panel functions with the VR simultaneously.	✓				
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Name: ____________________ (Optional) Occupation: Electronics Engineer Date: ________

SURVEY STATEMENTS		Rating				
		5	4	3	2	1
FUNCTIONAL SUITABILITY						
Completeness	1. The device function according to the specifications.		✓			
Correctness	2. The device provides an accurate result.		✓			
Appropriateness	3. The device fulfills its function.		✓			
PERFORMANCE EFFICIENCY						
Time behavior	1. The vision screening test conducted using the device works faster compared to the traditional test.		✓			
Resource utilization	2. The things are done correctly, minimum time with the minimum cost incurred, and no waste of resources.	✓				
COMPATIBILITY						
Co-existence	1. The VR and control panel work together without problem or conflict.	✓				
Interoperability	2. The control panel functions with the VR simultaneously.	✓				
USABILITY						
Appropriateness recognizability	1. The device can be recognized as a tool to detect risk factors of amblyopia.		✓			
Learnability	2. The instructions can be understood easily.	✓				
Operability	3. The controls can be easy to operate.	✓				
User error protection	4. The device protects users against making errors.	✓				
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RELIABILITY						
Maturity	1. The device is stable in conducting vision screening.	✓				
Availability	2. The device can be used anytime.	✓				
Fault tolerance	3. The device works even when there are some hardware or software faults.		✓			
Recoverability	4. The data can be recovered in case of system failure		✓			
SECURITY						
Confidentiality	1. The data is accessible only to authorized people.	✓				
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Instruction: Please rate whether you strongly disagree or strongly agree. Check one response of the following statements. Rate 1 - if strongly disagree 2 – disagree 3 - neither agree nor disagree 4 - agree 5 - if strongly agree

Name: ______________________ (Optional) Occupation: Student Date: ________

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		5	4	3	2	1
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Completeness	1. The device function according to the specifications.	✓				
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Name: ______________________ Occupation: Student Date: ________
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SURVEY STATEMENTS		Rating 5	4	3	2	1
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SURVEY STATEMENTS		Rating 5	4	3	2	1
FUNCTIONAL SUITABILITY						
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Confidentiality	1. The data is accessible only to authorized people.	✓				
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The students involved prior to this study need to conduct a survey for evaluation of different aspects of the proponent, entitled "*IVRead: INTERACTIVE VIRTUAL REALITY FOR EARLY DETECTION OF AMBLYOPIA FOR KINDERGARTEN PUPILS.*"

Instruction: Please rate whether you strongly disagree or strongly agree. Check one response of the following statements. Rate 1 - if strongly disagree 2 – disagree 3 - neither agree nor disagree 4 - agree 5 - if strongly agree

Name: ______________________ (Optional) Occupation: Student Date: ________

SURVEY STATEMENTS		Rating				
		5	4	3	2	1
FUNCTIONAL SUITABILITY						
Completeness	1. The device function according to the specifications.	✓				
Correctness	2. The device provides an accurate result.		✓			
Appropriateness	3. The device fulfills its function.		✓			
PERFORMANCE EFFICIENCY						
Time behavior	1. The vision screening test conducted using the device works faster compared to the traditional test.		✓			
Resource utilization	2. The things are done correctly, minimum time with the minimum cost incurred, and no waste of resources.		✓			
COMPATIBILITY						
Co-existence	1. The VR and control panel work together without problem or conflict.	✓				
Interoperability	2. The control panel functions with the VR simultaneously.	✓				
USABILITY						
Appropriateness recognizability	1. The device can be recognized as a tool to detect risk factors of amblyopia.		✓			
Learnability	2. The instructions can be understood easily.		✓			
Operability	3. The controls can be easy to operate.	✓				
User error protection	4. The device protects users against making errors.	✓				
User interface aesthetics	5. The user interface is pleasing to the eye.	✓				
RELIABILITY						
Maturity	1. The device is stable in conducting vision screening.		✓			
Availability	2. The device can be used anytime.	✓				
Fault tolerance	3. The device works even when there are some hardware or software faults.	✓				
Recoverability	4. The data can be recovered in case of system failure		✓			
SECURITY						
Confidentiality	1. The data is accessible only to authorized people.	✓				
Integrity	2. The device prevents unauthorized access to or modification of data.		✓			
Accountability	3. Any alteration in the results is recorded.		✓			
MAINTAINABILITY						
Analyzability	1. The sequence process of the entire program can be easy to understand.	✓				
Testability	2. The device is automated that can perform three tests, namely visual acuity, ocular motility, and refractive error detection.		✓			

TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES
Ayala Blvd., Ermita, Manila, 1000, Philippines
Tel. No. +632-301-3001 | Fax No. +632-521-4063
Email: tup@tup.edu.ph | Website: www.tup.edu.ph

QUESTIONNAIRE

The students involved prior to this study need to conduct a survey for evaluation of different aspects of the proponent, entitled "*VRead: INTERACTIVE VIRTUAL REALITY FOR EARLY DETECTION OF AMBLYOPIA FOR KINDERGARTEN PUPILS.*"

Instruction: Please rate whether you strongly disagree or strongly agree. Check one response of the following statements. Rate 1 - if strongly disagree 2 – disagree 3 - neither agree nor disagree 4 - agree 5 - if strongly agree

Name: ______________________ Occupation: Student Date: ________
(Optional)

SURVEY STATEMENTS		Rating				
		5	4	3	2	1
FUNCTIONAL SUITABILITY						
Completeness	1. The device function according to the specifications.	✓				
Correctness	2. The device provides an accurate result.		✓			
Appropriateness	3. The device fulfills its function.	✓				
PERFORMANCE EFFICIENCY						
Time behavior	1. The vision screening test conducted using the device works faster compared to the traditional test.	✓				
Resource utilization	2. The things are done correctly, minimum time with the minimum cost incurred, and no waste of resources.		✓			
COMPATIBILITY						
Co-existence	1. The VR and control panel work together without problem or conflict.	✓				
Interoperability	2. The control panel functions with the VR simultaneously.	✓				
USABILITY						
Appropriateness recognizability	1. The device can be recognized as a tool to detect risk factors of amblyopia.		✓			
Learnability	2. The instructions can be understood easily.		✓			
Operability	3. The controls can be easy to operate.	✓				
User error protection	4. The device protects users against making errors.		✓			
User interface aesthetics	5. The user interface is pleasing to the eye.	✓				
RELIABILITY						
Maturity	1. The device is stable in conducting vision screening.	✓				
Availability	2. The device can be used anytime.	✓				
Fault tolerance	3. The device works even when there are some hardware or software faults.		✓			
Recoverability	4. The data can be recovered in case of system failure		✓			
SECURITY						
Confidentiality	1. The data is accessible only to authorized people.	✓				
Integrity	2. The device prevents unauthorized access to or modification of data.		✓			
Accountability	3. Any alteration in the results is recorded.	✓				
MAINTAINABILITY						
Analyzability	1. The sequence process of the entire program can be easy to understand.	✓				
Testability	2. The device is automated that can perform three tests, namely visual acuity, ocular motility, and refractive error detection.		✓			

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Ayala Blvd., Ermita, Manila, 1000, Philippines
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Email: tup@tup.edu.ph | Website: www.tup.edu.ph

QUESTIONNAIRE

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Instruction: Please rate whether you strongly disagree or strongly agree. Check one response of the following statements. Rate 1 - if strongly disagree 2 – disagree 3 - neither agree nor disagree 4 - agree 5 - if strongly agree

Name: ______________________ (Optional)   Occupation: Opthalmologist   Date: ________

SURVEY STATEMENTS		Rating				
		5	4	3	2	1
FUNCTIONAL SUITABILITY						
Completeness	1. The device function according to the specifications.	✓				
Correctness	2. The device provides an accurate result.			✓		
Appropriateness	3. The device fulfills its function.		✓			
PERFORMANCE EFFICIENCY						
Time behavior	1. The vision screening test conducted using the device works faster compared to the traditional test.		✓			
Resource utilization	2. The things are done correctly, minimum time with the minimum cost incurred, and no waste of resources.		✓			
COMPATIBILITY						
Co-existence	1. The VR and control panel work together without problem or conflict.	✓				
Interoperability	2. The control panel functions with the VR simultaneously.	✓				
USABILITY						
Appropriateness recognizability	1. The device can be recognized as a tool to detect risk factors of amblyopia.	✓				
Learnability	2. The instructions can be understood easily.		✓			
Operability	3. The controls can be easy to operate.		✓			
User error protection	4. The device protects users against making errors.		✓			
User interface aesthetics	5. The user interface is pleasing to the eye.			✓		
RELIABILITY						
Maturity	1. The device is stable in conducting vision screening.		✓			
Availability	2. The device can be used anytime.		✓			
Fault tolerance	3. The device works even when there are some hardware or software faults.	✓				
Recoverability	4. The data can be recovered in case of system failure	✓				
SECURITY						
Confidentiality	1. The data is accessible only to authorized people.	✓				
Integrity	2. The device prevents unauthorized access to or modification of data.	✓				
Accountability	3. Any alteration in the results is recorded.	✓				
MAINTAINABILITY						
Analyzability	1. The sequence process of the entire program can be easy to understand.	✓				
Testability	2. The device is automated that can perform three tests, namely visual acuity, ocular motility, and refractive error detection.	✓				

TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES
Ayala Blvd., Ermita, Manila, 1000, Philippines
Tel. No. +632-301-3001 | Fax No. +632-521-4063
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QUESTIONNAIRE

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Instruction: Please rate whether you strongly disagree or strongly agree. Check one response of the following statements. Rate 1 - if strongly disagree 2 – disagree 3 - neither agree nor disagree 4 - agree 5 - if strongly agree

Name: ____________________ (Optional) Occupation: Medical Optics Physicist Date: ________

SURVEY STATEMENTS		Rating 5	4	3	2	1
FUNCTIONAL SUITABILITY						
Completeness	1. The device function according to the specifications.	✓				
Correctness	2. The device provides an accurate result.			✓		
Appropriateness	3. The device fulfills its function.		✓			
PERFORMANCE EFFICIENCY						
Time behavior	1. The vision screening test conducted using the device works faster compared to the traditional test.		✓			
Resource utilization	2. The things are done correctly, minimum time with the minimum cost incurred, and no waste of resources.		✓			
COMPATIBILITY						
Co-existence	1. The VR and control panel work together without problem or conflict.	✓				
Interoperability	2. The control panel functions with the VR simultaneously.	✓				
USABILITY						
Appropriateness recognizability	1. The device can be recognized as a tool to detect risk factors of amblyopia.		✓			
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Operability	3. The controls can be easy to operate.	✓				
User error protection	4. The device protects users against making errors.	✓				
User interface aesthetics	5. The user interface is pleasing to the eye.		✓			
RELIABILITY						
Maturity	1. The device is stable in conducting vision screening.		✓			
Availability	2. The device can be used anytime.	✓				
Fault tolerance	3. The device works even when there are some hardware or software faults.		✓			
Recoverability	4. The data can be recovered in case of system failure		✓			
SECURITY						
Confidentiality	1. The data is accessible only to authorized people.	✓				
Integrity	2. The device prevents unauthorized access to or modification of data.	✓				
Accountability	3. Any alteration in the results is recorded.		✓			
MAINTAINABILITY						
Analyzability	1. The sequence process of the entire program can be easy to understand.	✓				
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Instruction: Please rate whether you strongly disagree or strongly agree. Check one response of the following statements. Rate 1 - if strongly disagree 2 – disagree 3 - neither agree nor disagree 4 - agree 5 - if strongly agree

Name: ______________________ (Optional) Occupation: Electronics Engineer Date: ________

SURVEY STATEMENTS		Rating				
		5	4	3	2	1
FUNCTIONAL SUITABILITY						
Completeness	1. The device function according to the specifications.	✓				
Correctness	2. The device provides an accurate result.			✓		
Appropriateness	3. The device fulfills its function.		✓			
PERFORMANCE EFFICIENCY						
Time behavior	1. The vision screening test conducted using the device works faster compared to the traditional test.		✓			
Resource utilization	2. The things are done correctly, minimum time with the minimum cost incurred, and no waste of resources.		✓			
COMPATIBILITY						
Co-existence	1. The VR and control panel work together without problem or conflict.	✓				
Interoperability	2. The control panel functions with the VR simultaneously.	✓				
USABILITY						
Appropriateness recognizability	1. The device can be recognized as a tool to detect risk factors of amblyopia.		✓			
Learnability	2. The instructions can be understood easily.		✓			
Operability	3. The controls can be easy to operate.	✓				
User error protection	4. The device protects users against making errors.		✓			
User interface aesthetics	5. The user interface is pleasing to the eye.		✓			
RELIABILITY						
Maturity	1. The device is stable in conducting vision screening.	✓				
Availability	2. The device can be used anytime.		✓			
Fault tolerance	3. The device works even when there are some hardware or software faults.		✓			
Recoverability	4. The data can be recovered in case of system failure	✓				
SECURITY						
Confidentiality	1. The data is accessible only to authorized people.		✓			
Integrity	2. The device prevents unauthorized access to or modification of data.		✓			
Accountability	3. Any alteration in the results is recorded.		✓			
MAINTAINABILITY						
Analyzability	1. The sequence process of the entire program can be easy to understand.	✓				
Testability	2. The device is automated that can perform three tests, namely visual acuity, ocular motility, and refractive error detection.		✓			

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Instruction: Please rate whether you strongly disagree or strongly agree. Check one response of the following statements. Rate 1 - if strongly disagree 2 – disagree 3 - neither agree nor disagree 4 - agree 5 - if strongly agree

Name: ______________________ (Optional) Occupation: Grandmother Date: ________

SURVEY STATEMENTS		Rating				
		5	4	3	2	1
FUNCTIONAL SUITABILITY						
Completeness	1. The device function according to the specifications.	✓				
Correctness	2. The device provides an accurate result.	✓				
Appropriateness	3. The device fulfills its function.	✓				
PERFORMANCE EFFICIENCY						
Time behavior	1. The vision screening test conducted using the device works faster compared to the traditional test.	✓				
Resource utilization	2. The things are done correctly, minimum time with the minimum cost incurred, and no waste of resources.			✓		
COMPATIBILITY						
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User error protection	4. The device protects users against making errors.	✓				
User interface aesthetics	5. The user interface is pleasing to the eye.		✓			
RELIABILITY						
Maturity	1. The device is stable in conducting vision screening.	✓				
Availability	2. The device can be used anytime.		✓			
Fault tolerance	3. The device works even when there are some hardware or software faults.		✓			
Recoverability	4. The data can be recovered in case of system failure	✓				
SECURITY						
Confidentiality	1. The data is accessible only to authorized people.		✓			
Integrity	2. The device prevents unauthorized access to or modification of data.		✓			
Accountability	3. Any alteration in the results is recorded.		✓			
MAINTAINABILITY						
Analyzability	1. The sequence process of the entire program can be easy to understand.		✓			
Testability	2. The device is automated that can perform three tests, namely visual acuity, ocular motility, and refractive error detection.		✓			

APPENDIX B

Progrm Codes

```
import RPi.GPIO as GPIO                                        #import the
RPi.GPIO module to allow us use the board GPIO pins.

import pyrebase                                       #import the pyrebase
module which allows us to communicate with the firebase servers.

import time

import picamera

import datetime

import cv2

import numpy as np

import imutils

import sys

import os


def LightReflex():

   print('initializing,,,')

   time.sleep(2)

   print('Light Reflex Test')

   print('Press Start')

   time.sleep(2)


   whiteLED = 11

   startLED = 13

   cameraLRT = picamera.PiCamera()

   GPIO.setmode(GPIO.BOARD)                                    #Set the
GPIO Scheme numbering system to the BCM mode.

   GPIO.setwarnings(False)                                  #disable
warnings

   GPIO.setup(whiteLED,GPIO.OUT)

   GPIO.setup(startLED,GPIO.OUT)
```

```
white_pwm = GPIO.PWM(whiteLED,1000)
start_pwm = GPIO.PWM(startLED,1000)
start_pwm.start(10)
white_pwm.start(0)

fileName = '/home/pi/Desktop/LRT/LRT' + '.jpg'
cameraLRT.resolution = (2560,1920)
print('Device Ready')

config = {                                    #define a dictionary named config
with several key-value pairs that configure the connection to the database.
  "apiKey": "B60CPEkohkrk72rcgpB6XWaifGR2ziBM6leipPcI",
  "authDomain": "ivread-controls-2022.firebaseapp.com",
  "databaseURL": "https://ivread-controls-2022-default-rtdb.asia-
southeast1.firebasedatabase.app/",
  "storageBucket": "ivread-controls-2022.appspot.com"
}

firebase = pyrebase.initialize_app(config)
db = firebase.database()

def LRTProcess():
  try:
    #import image
    image = cv2.imread(fileName)
    resize = cv2.resize(image, (1920, 1440))
    rotate = imutils.rotate(resize, angle=0)
```

```
alphaR = 3 # Contrast control (1.0-3.0)
betaR = 30 # Brightness control (0-100)
bimgR = cv2.convertScaleAbs(rotate, alpha=alphaR, beta=betaR)

#Height and Width of the image
height, width, depth = image.shape
#print(height, width, depth)

#FOR RIGHT EYE

#cropping of image
yr = 550
hr = 400
xr = 500
wr = 400
r_eye = bimgR[yr:yr+hr, xr:xr+hr]

#EYEBALL DETECTION
gray1 = cv2.cvtColor(r_eye, cv2.COLOR_BGR2GRAY)
gray1 = cv2.medianBlur(gray1, 3)
rows1 = gray1.shape[0]
circles1 = cv2.HoughCircles(gray1, cv2.HOUGH_GRADIENT, 4, rows1 / 8,
                            param1=120, param2=50,
                            minRadius=52, maxRadius= 55)
detected_circles1 = np.uint16(np.around(circles1))

#EYEBALL POINTS
for pt1 in detected_circles1[0, :]:
```

```
    x1, y1, r1 = pt1[0], pt1[1], pt1[2]
    #circle outline
    cv2.circle(r_eye, (x1, y1), r1, (0, 0, 255), 2)
    A = x1-r1   # Value of A
    C = x1+r1   # Value of B




r_eye = cv2.line(r_eye, (A,0), (A,400), (0,0,255), 2)
r_eye = cv2.line(r_eye, (C,0), (C,400), (0,0,255), 2)
# END OF HOUGH DETECTION

# Setup SimpleBlobDetector parameters.
params1 = cv2.SimpleBlobDetector_Params()
# Change thresholds
params1.minThreshold = 240
params1.maxThreshold = 255

# Filter by Area.
params1.filterByArea = True
params1.minArea = 2

 # Filter by Color
params1.filterByColor = True
params1.blobColor = 255

 # Filter by Circularity
params1.filterByCircularity = True
```

```
params1.minCircularity = 0.3

# Filter by Convexity
params1.filterByConvexity = True
params1.minConvexity = 0.87

# Filter by Inertia
params1.filterByInertia = True
params1.minInertiaRatio = 0.01

# Create a detector with the parameters
ver1 = (cv2.__version__).split('.')
if int(ver1[0]) < 3:
        detector1 = cv2.SimpleBlobDetector(params1)
else:
        detector1 = cv2.SimpleBlobDetector_create(params1)

# Detect blobs.
keypoints1 = detector1.detect(gray1)

#POINT OF BLOB DETECTION
for keypoint1 in keypoints1:
    XR = round(keypoint1.pt[0])
    YR = round(keypoint1.pt[1])
    ZR = round(keypoint1.size)

#Setting the Value of E
B = XR
```

```
AC = C-A
AB = B-A
#END FOR RIGHT


#FOR LEFT EYE

alphaL = 3 # Contrast control (1.0-3.0)
betaL = 30 # Brightness control (0-100)
bimgL = cv2.convertScaleAbs(rotate, alpha=alphaL, beta=betaL)

#cropping of image
yl = 550
hl = 400
xl = 1100
wl = 400
l_eye = bimgL[yl:yl+hl, xl:xl+hl]



#EYEBALL DETECTION
gray2 = cv2.cvtColor(l_eye, cv2.COLOR_BGR2GRAY)
gray2 = cv2.medianBlur(gray2, 5)
rows2 = gray2.shape[0]
circles2 = cv2.HoughCircles(gray2, cv2.HOUGH_GRADIENT, 4, rows2 / 8,
                           param1=120, param2=60,
                           minRadius=52, maxRadius= 55)
detected_circles2 = np.uint16(np.around(circles2))
```

```
#EYEBALL POINTS
for pt2 in detected_circles2[0, :]:
    x2, y2, r2 = pt2[0], pt2[1], pt2[2]
    #circle outline
    cv2.circle(l_eye, (x2, y2), r2, (0, 0, 255), 2)
    D = x2-r2   # Value of D
    F = x2+r2   # Value of F




l_eye = cv2.line(l_eye, (D,0), (D,400), (0,0,255), 2)
l_eye = cv2.line(l_eye, (F,0), (F,400), (0,0,255), 2)
# END OF HOUGH DETECTION

# Setup SimpleBlobDetector parameters.
params2 = cv2.SimpleBlobDetector_Params()
# Change thresholds
params2.minThreshold = 240
params2.maxThreshold = 255

# Filter by Area.
params2.filterByArea = True
params2.minArea = 2

 # Filter by Color
params2.filterByColor = True
params2.blobColor = 255
```

```
 # Filter by Circularity
params2.filterByCircularity = True
params2.minCircularity = 0.3

# Filter by Convexity
params2.filterByConvexity = True
params2.minConvexity = 0.87

# Filter by Inertia
params2.filterByInertia = True
params2.minInertiaRatio = 0.01

# Create a detector with the parameters
ver2 = (cv2.__version__).split('.')
if int(ver2[0]) < 3:
        detector2 = cv2.SimpleBlobDetector(params2)
else:
        detector2 = cv2.SimpleBlobDetector_create(params2)

# Detect blobs.
keypoints2 = detector2.detect(gray2)

#POINT OF BLOB DETECTION
for keypoint2 in keypoints2:
    XL= round(keypoint2.pt[0])
    YL = round(keypoint2.pt[1])
    ZL = round(keypoint2.size)
```

```
            #Setting the Value of E
            E = XL

            DF = F-D
            DE = E-D

            #END FOR LEFT EYE

            #COMPUTATION FOR CCLRR

            CCLRR = round((AB + DE)/(AC+DF),7)

            db.child("Results").child("resLightReflex").child("lReflex").set(str(CCLRR))
        except:
            db.child("Results").child("resLightReflex").child("lReflex").set(str(404))
    try:
        while True:                                                    #the beginning of the
main programtake an instance from the firebase database which is pointing to the root
directory of your database.
            LEDState = db.child("RPiCommands").child("RPiComms").get()

            if LEDState.val()=="ONledLR":
                white_pwm.ChangeDutyCycle(10)
                print('Light Reflex Test')
            elif LEDState.val()=="LRcapture":
                white_pwm.ChangeDutyCycle(100)
                cameraLRT.capture(fileName)
```

```
                time.sleep(1)
                print('LRT captured')
            elif LEDState.val()=="OFFledLR":
                white_pwm.ChangeDutyCycle(0)
                LRTProcess()
                time.sleep(1)
                print('Data Uploaded')
                time.sleep(0.5)
                print('View Results')
            elif LEDState.val()=="stopLRT":
                LightReflex.close()
                LightReflex()


    except KeyboardInterrupt:
        cameraLRT.close()
        GPIO.cleanup()
    except FileNotFoundError as fnf_error:
        print(fnf_error)
    except AssertionError as error:
        print(error)
        print("Image cannot be processed")
LightReflex()
```

```
import cv2

import numpy as np

import pyrebase

import RPi.GPIO as GPIO                                        #import the
RPi.GPIO module to allow us use the board GPIO pins.
#import the pyrebase module which allows us to communicate with the firebase servers.

import time

import picamera




print('initializing,,,')

print('Refractive Error Detection')

print('Press Start')


redLED = 37

startLED = 35

cameraREFT = picamera.PiCamera()

GPIO.setmode(GPIO.BOARD)                                        #Set the
GPIO Scheme numbering system to the BCM mode.

GPIO.setwarnings(False)                                  #disable warnings

GPIO.setup(redLED,GPIO.OUT)

GPIO.setup(startLED,GPIO.OUT)

red_pwm = GPIO.PWM(redLED,1000)

start_pwm = GPIO.PWM(startLED,1000)

start_pwm.start(10)
```

```
red_pwm.start(0)

fileNameL = '/home/pi/Desktop/REFT/L' + '.jpg'
fileNameR = '/home/pi/Desktop/REFT/R' + '.jpg'
cameraREFT.rotation = 180
cameraREFT.resolution = (1920,1440)

print('Device Ready')

config = {                                          #define a dictionary named config with several key-value pairs that configure the connection to the database.
    "apiKey": "B60CPEkohkrk72rcgpB6XWaifGR2ziBM6leipPcI",
    "authDomain": "ivread-controls-2022.firebaseapp.com",
    "databaseURL": "https://ivread-controls-2022-default-rtdb.asia-southeast1.firebasedatabase.app/",
    "storageBucket": "ivread-controls-2022.appspot.com"
}

firebase = pyrebase.initialize_app(config)
db = firebase.database()

def LeftProcess():
    try:
        # Load image and crop
        image = cv2.imread(fileNameL)
        resize = cv2.resize(image, (560, 420))
        yl = 140
        hl = 150
```

```
xl = 200
wl = 150
cimage1 = resize[yl:yl+hl, xl:xl+wl]


    # Convert to greyscale and enhance edges
gray1 = cv2.cvtColor(resize, cv2.COLOR_BGR2GRAY)
gray1 = cv2.GaussianBlur(gray1,(5,5),0);
gray1 = cv2.medianBlur(gray1,5)

    # Fourier transform
f1 = np.fft.fft2(gray1)

    # Apply shift to place DC component in the center
fshift1 = np.fft.fftshift(f1)

    # Power magnitude spectrum of the fft
magspec1 = 20*np.log(np.abs(fshift1))

    # Phase Spectrum of the fftd:  0
phase1 = np.angle(fshift1)


    # Selecting region for peak values - Magnitude
magL = magspec1
m1= magL[178:183, 277:282]
m2= magL[207:212, 239:244]
```

```
    # Peak values for each region
pkL1 = np.amax(m1)
pkL2 = np.amax(m2)

    # Selecting region for peak values - Phase
phL = phase1
p1 = phL[178:183, 277:282]
p2 = phL[207:212, 239:244]

    # Peak values for each region
pkL3 = np.amax(p1)
pkL4 = np.amax(p2)

    # Constants
pupilsize = 6

    # Magnitude and Phase
rhoL = np.abs(pkL1-pkL2)
thetaL = np.abs(pkL3-pkL4)

    # Zernike Coefficients
zL1 = 2*np.square(rhoL)-1
zL2 = np.square(rhoL)*np.cos(2*thetaL);
zL3 = np.square(rhoL)*np.sin(2*thetaL);

    # Convert to meters
zL1 = zL1/10**6;
```

```
zL2 = zL2/10**6;
zL3 = zL3/10**6;

    # Computation : Left Eye
if (zL3==0):
    alphaL = (-1)*np.sign(zL1)*np.pi/4;   #special case when z3 is equal to
zero
else:
    alphaL = (-1)*0.5*np.arctan(zL1/zL3);

if (abs(zL3)<abs(zL1)):
    AL = zL1*2*np.sqrt(6)/np.sin(2*alphaL);
else:
    AL = -zL3*2*np.sqrt(6)/np.cos(2*alphaL);

axL = (-1)*180*alphaL/np.pi; # AXIAL VALUE

if (AL<=0):
    AL = (-1)*AL;
    axL = axL-90;
if (axL<=0):
    axL = axL+180;

DL = zL2*2*np.sqrt(3)-AL/2;
cylL= -np.abs(-20*DL/((pupilsize/2000)**2)); # CYLINDRICAL VALUE
sphL = -20*AL/((pupilsize/2000)**2); # SPHERICAL VALUE

db.child("Results").child("resRefractive").child("leftAX").set(str(round(axL)))
```

```
        db.child("Results").child("resRefractive").child("leftCY").set(str(round(cylL)))
        db.child("Results").child("resRefractive").child("leftSP").set(str(round(sphL)))
        print(round(axL),round(sphL),round(cylL))
    except:
        db.child("Results").child("resRefractive").child("rightAX").set(str(404))
        db.child("Results").child("resRefractive").child("rightCY").set(str(404))
        db.child("Results").child("resRefractive").child("rightSP").set(str(r404))


def RightProcess():
    try:
        # Load image and crop
        image = cv2.imread(fileNameR)
        resize = cv2.resize(image, (560, 420))
        yl = 140
        hl = 150
        xl = 200
        wl = 150
        cimage1 = resize[yl:yl+hl, xl:xl+wl]



            # Convert to greyscale and enhance edges
        gray1 = cv2.cvtColor(resize, cv2.COLOR_BGR2GRAY)
        gray1 = cv2.GaussianBlur(gray1,(5,5),0);
        gray1 = cv2.medianBlur(gray1,5)

            # Fourier transform
        f1 = np.fft.fft2(gray1)
```

```
	# Apply shift to place DC component in the center
fshift1 = np.fft.fftshift(f1)

	# Power magnitude spectrum of the fft
magspec1 = 20*np.log(np.abs(fshift1))

	# Phase Spectrum of the fftd:  0
phase1 = np.angle(fshift1)


	# Selecting region for peak values - Magnitude
magL = magspec1
m1= magL[178:183, 277:282]
m2= magL[207:212, 239:244]


	# Peak values for each region
pkL1 = np.amax(m1)
pkL2 = np.amax(m2)

	# Selecting region for peak values - Phase
phL = phase1
p1 = phL[178:183, 277:282]
p2 = phL[207:212, 239:244]

	# Peak values for each region
pkL3 = np.amax(p1)
```

```
pkL4 = np.amax(p2)

    # Constants
pupilsize = 6

    # Magnitude and Phase
rhoL = np.abs(pkL1-pkL2)
thetaL = np.abs(pkL3-pkL4)

    # Zernike Coefficients
zL1 = 2*np.square(rhoL)-1
zL2 = np.square(rhoL)*np.cos(2*thetaL);
zL3 = np.square(rhoL)*np.sin(2*thetaL);

    # Convert to meters
zL1 = zL1/10**6;
zL2 = zL2/10**6;
zL3 = zL3/10**6;

    # Computation : Left Eye
if (zL3==0):
    alphaL = (-1)*np.sign(zL1)*np.pi/4;   #special case when z3 is equal to
zero
else:
    alphaL = (-1)*0.5*np.arctan(zL1/zL3);

if (abs(zL3)<abs(zL1)):
    AL = zL1*2*np.sqrt(6)/np.sin(2*alphaL);
```

```
            else:
                AL = -zL3*2*np.sqrt(6)/np.cos(2*alphaL);

            axL = (-1)*180*alphaL/np.pi; # AXIAL VALUE

            if (AL<=0):
                AL = (-1)*AL;
                axL = axL-90;
            if (axL<=0):
                axL = axL+180;

            DL = zL2*2*np.sqrt(3)-AL/2;
            cylL= -np.abs(-20*DL/((pupilsize/2000)**2)); # CYLINDRICAL VALUE
            sphL = -20*AL/((pupilsize/2000)**2); # SPHERICAL VALUE


db.child("Results").child("resRefractive").child("rightAX").set(str(round(axL)))

db.child("Results").child("resRefractive").child("rightCY").set(str(round(cylL)))

db.child("Results").child("resRefractive").child("rightSP").set(str(round(sphL)))
            print(round(axL),round(sphL),round(cylL))
        except:
            db.child("Results").child("resRefractive").child("rightAX").set(str(404))
            db.child("Results").child("resRefractive").child("rightCY").set(str(404))
            db.child("Results").child("resRefractive").child("rightSP").set(str(r404))

try:
```

```
    while True:                                                     #the beginning of the
main program.

        LEDState = db.child("RPiCommands").child("RPiComms").get()

        if LEDState.val()=="ONleftRE":
            red_pwm.ChangeDutyCycle(5)
            print('Refractive Left')
            cameraREFT.start_preview()
            time.sleep(5)
        if LEDState.val()=="CAPleftRE":
            red_pwm.ChangeDutyCycle(10)
            cameraREFT.capture(fileNameL)
            time.sleep(1)
            print('Left captured')
        elif LEDState.val()=="OFFleftRE":
            red_pwm.ChangeDutyCycle(0)
            LeftProcess()
            time.sleep(1)
            print('Data Uploaded')
            print('Proceed to Right Eye')
        elif LEDState.val()=="ONrightRE":
            red_pwm.ChangeDutyCycle(5)
            print('Refractive Right')
        elif LEDState.val()=="CAPrightRE":
            red_pwm.ChangeDutyCycle(10)
            cameraREFT.capture(fileNameR)
            time.sleep(1)
```

```
            print('Right captured')
        elif LEDState.val()=="OFFrightRE":
            red_pwm.ChangeDutyCycle(0)
            RightProcess()
            time.sleep(1)
            print('Data Uploaded')
            time.sleep(0.5)
            print('View Results!')
            time.sleep(5)
        elif LEDState.val()=="stopREFT":
            cameraREFT.stop_preview()

except KeyboardInterrupt:
    cameraREFT.close()
    cameraREFT.stop_preview()
    GPIO.cleanup()
```

APPENDIX C

Bill of Materials

Bills of Materials

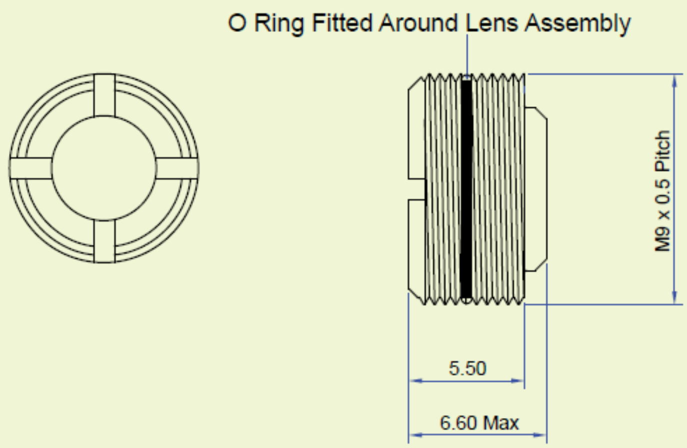
MATERIALS	QUANTITY	PRICE	COST
Collimating Lens	1	Php 500.00	Php 500.00
LED	2	Php 4.00	Php 8.00
Microlens Array	1	Php 32,000.00	Php 32,000.00
Power supply	1	Php 1,800.00	Php 1,800.00
Raspberry Pi 3	2	Php 5,000.00	Php 10,000.00
USB Camera	2	Php 3,000.00	Php 6,000.00
Earphones	1	Php 500.00	Php 500.00
Foam Cartridge	1	Php 200.00	Php 200.00
SD Card	2	Php 500.00	Php 1,000.00
Camera holder	2	Php 240.00	Php 480.00
HDMI to micro–HDMI Cable	1	Php 500.00	Php 500.00
HDMI to HDMI cable	1	Php 65.00	Php 65.00
Insulation Foam	1	Php 1,440.00	Php 1,440.00
Foam Strap	1	Php 100.00	Php 100.00
VR lens	2	Php 120.00	Php 120.00
3D Printing Service	1	Php 42,000.00	Php 42,000.00
		Total	**Php 112,913.00**

APPENDIX D

Specifications and Data Sheets

COLLIMATING LENS

S M9 x 0.5 Lens Assembly



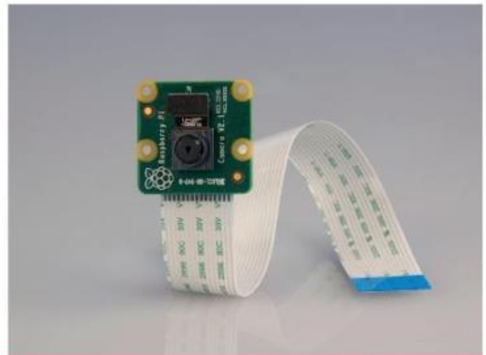
Information					
RS Part Number	RS127-137	RS127-1542	RS127-1541	RS127-1539	RS127-1538
Global Laser Part Number	1125-360-000	1125-364-000	1125-363-000	1125-362-000	1125-361-000
Description	S Lens Assembly	HG Lens Assembly	C3 Lens Assembly	C2 Lens Assembly	C1 Lens Assembly
Thread	M9 x 0.5				
Number of Elements	1				
Lens Material	Plastic	Glass	Plastic		
Wavelength	670nm				
Focal Length (mm)	7.9 ±0.05	11	7.9 ±0.05		
Numerical Aperture	0.3				
Clear Aperture (mm)	5	6.5	3.5	2	1
A/R Coated	Yes (MgF_2)				
Exit Beam Size (mm) *	~5 x 2.2	~6.5 x 2.5	~3.5 x 2.2	~2	~1
Beam Divergence (mRad) *	≤0.2	≤0.15	≤0.25	≤0.5	≤1
Focus Spot Size @ 50mm (1e²) (µm) *	~11 by 26	~8 by 18	~16 by 26	~31	~59
Transmission Loss @ 650nm *	~30%	~37%	~47%	~73%	~82%
Transmission Loss @ 650nm #	~20%	~25%	~33%	~70%	~80%

NOTES

All specifications are typical @ 25°C
* Calculated with a laser diode with a 8 x 30° divergence angle (FWHM)
# Calculated with a laser diode with a 8 x 20° divergence angle (FWHM)

USB CAMERA

Raspberry Pi



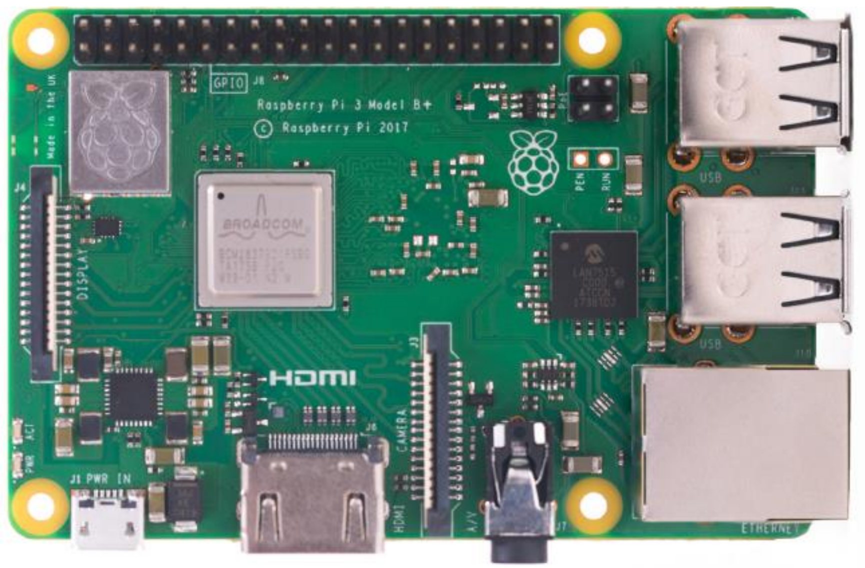
Camera Module

Product Name	**Raspberry Pi Camera Module**
Product Description	High Definition camera module compatible with all Raspberry Pi models. Provides high sensitivity, low crosstalk and low noise image capture in an ultra small and lightweight design. The camera module connects to the Raspberry Pi board via the CSI connector designed specifically for interfacing to cameras. The CSI bus is capable of extremely high data rates, and it exclusively carries pixel data to the processor.
RS Part Numer	**913-2664**

Specifications

Image Sensor	Sony IMX 219 PQ CMOS image sensor in a fixed-focus module
Resolution	8-megapixel
Still picture resolution	3280 x 2464
Max image transfer rate	1080p: 30fps (encode and decode) 720p: 60fps
Connection to Raspberry Pi	15-pin ribbon cable, to the dedicated 15-pin MIPI Camera Serial Interface (CSI-2).
Image control functions	Automatic exposure control Automatic white balance Automatic band filter Automatic 50/60 Hz luminance detection Automatic black level calibration
Temp range	Operating: -20° to 60° Stable image: -20° to 60°
Lens size	1/4"
Dimensions	23.86 x 25 x 9mm
Weight	3g

RASPBERRY PI 3B



The Raspberry Pi 3 Model B+ is the latest product in the Raspberry Pi 3 range, boasting a 64-bit quad core processor running at 1.4 GHz, dual-band 2.4 GHz and 5 GHz wireless LAN, Bluetooth 4.2/BLE, faster Ethernet, and PoE capability via a separate PoE HAT

The dual-band wireless LAN comes with modular compliance certification, allowing the board to be designed into end products with significantly reduced wireless LAN compliance testing, improving both cost and time to market.

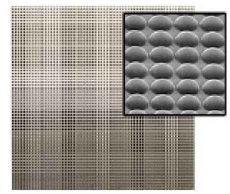
The Raspberry Pi 3 Model B+ maintains the same mechanical footprint as both the Raspberry Pi 2 Model B and the Raspberry Pi 3 Model B.

Processor:	Broadcom BCM2837B0, Cortex-A53 64-bit SoC @ 1.4GHz
Memory:	1GB LPDDR2 SDRAM
Connectivity:	■ 2.4GHz and 5GHz IEEE 802.11.b/g/n/ac wireless LAN, Bluetooth 4.2, BLE ■ Gigabit Ethernet over USB 2.0 (maximum throughput 300 Mbps) ■ 4 × USB 2.0 ports
Access:	Extended 40-pin GPIO header
Video & sound:	■ 1 × full size HDMI ■ MIPI DSI display port ■ MIPI CSI camera port ■ 4 pole stereo output and composite video port
Multimedia:	H.264, MPEG-4 decode (1080p30); H.264 encode (1080p30); OpenGL ES 1.1, 2.0 graphics
SD card support:	Micro SD format for loading operating system and data storage
Input power:	■ 5V/2.5A DC via micro USB connector ■ 5V DC via GPIO header ■ Power over Ethernet (PoE)–enabled (requires separate PoE HAT)
Environment:	Operating temperature, 0–50°C
Compliance:	For a full list of local and regional product approvals, please visit www.raspberrypi.org/products/raspberry -pi-3-model-b+
Production lifetime:	The Raspberry Pi 3 Model B+ will remain in production until at least January 2023.

MICROLENS ARRAY

THORLABS

Unmounted MLA Series Microlens Arrays



Description

Thorlabs Unmounted Microlens Arrays are best suited for Shack-Hartmann sensor applications. All lenslets are made from fused silica for excellent transmission characteristics from the deep UV to IR and have a plano-convex shape that allows nearly refraction limited spots.

The lenses are formed using photolithographic techniques based on semiconductor processing technology, which allows for excellent uniformity in the shape and position of each microlens, unlike some microlens arrays produced from molded epoxy.

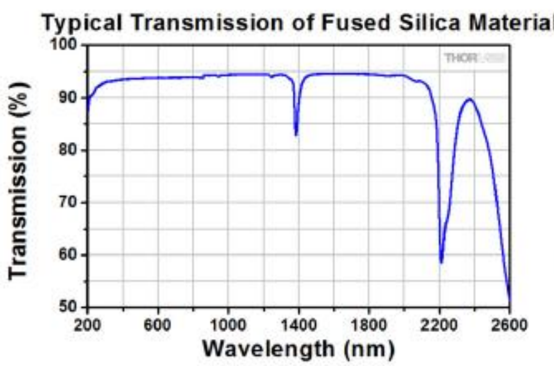
The MLA150-5C has a chrome mask that blocks light from being transmitted unless it goes through a microlens and therefore increases image contrast. The MLA150-7AR and MLA300-14AR have a broadband AR coating to reduce surface reflections in the 400 - 900 nm spectral region to below 1%.

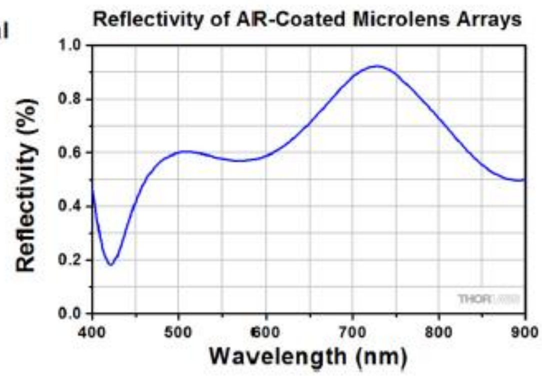
Specifications

Item #	MLA150-5C	MLA150-7AR	MLA300-14AR
Substrate Material	Fused Silica (Quartz)		
Wavelength Range	300 nm - 1100 nm	400 nm - 900 nm	
Array Size and Type	10 mm x 10 mm, Square Grid		
Lens Type	Round, Refractive, Plano-Convex		Square, Refractive, Plano-Convex
Lenslet Pitch	150 µm		300 µm
Lens Size	Ø140 µm (Cr Mask Hole)	Ø146 µm (Lens Diameter)	295 µm (Square)
AR Coating	No	Reflectivity <1% for 400 nm - 900 nm	
Chrome Apertures	Yes, Around Microlenses	No	
Geometric Parameters			
h, w	10 mm		
t	1.2 mm		
P	150 µm		300 µm
r	2.54 mm		6.5 mm
f[1]	5.6 mm		14.2 mm

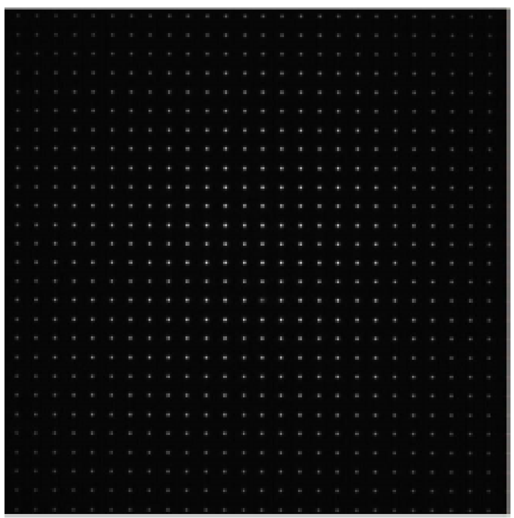
1 Nominal value, ±3% tolerance, Note: When built into a WFS, the effective focal length may differ.

Wavelength Characteristics





Spotfield Derived with the MLA150-5C Microlens Array



APPENDIX E

Data Gathered

VISUAL ACUITY DATA

	Visual Acuity (logMAR)			
Sample No.	iVRead (logMAR)	Clinical (logMAR)	Average	Difference
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0.7	0.7	0.7	0
5	1	1	1	0
6	0	0.1	0.05	-0.1
7	0	0.2	0.1	-0.2
8	0.4	0.4	0.4	0
9	0.1	0.1	0.1	0
10	0.2	0.2	0.2	0
11	0	0.1	0.05	-0.1
12	0	0	0	0
13	1.5	1.6	1.55	-0.1
14	0.6	0.7	0.65	-0.1
15	0.2	0.2	0.2	0
16	0.1	0.1	0.1	0
17	0.1	0.1	0.1	0
18	0	0	0	0
19	0	0	0	0
20	0.9	0.8	0.85	0.1
21	0.1	0.1	0.1	0
22	0.1	0	0.05	0.1
23	0.2	0.2	0.2	0
24	0.2	0.2	0.2	0
25	0.1	0.1	0.1	0
26	0.1	0.1	0.1	0
27	0	0	0	0
28	1.2	1.3	1.25	-0.1
29	0.6	0.7	0.65	-0.1
30	1	1	1	0
			Avg Diff	-0.02
			Lower	-0.139610402
			Upper	0.09961040204

In the visual acuity test, the results from the iVRead are compared to the traditional visual acuity test where the subject read the letters in the vision chart monocularly.

Sample 1	iVRead
Sample 2	Clinical

	Sample 1	Sample 2
Sample size	30	30
Lowest value	0.0000	0.0000
Highest value	1.5000	1.6000
Median	0.1000	0.1000
95% CI for the median	0.01750 to 0.2000	0.1000 to 0.2000
Interquartile range	0.0000 to 0.6000	0.0000 to 0.7000

Hodges-Lehmann median difference	0.0000
95% Confidence interval	0.0000 to 0.05000

Wilcoxon test (paired samples)

Number of positive differences	7
Number of negative differences	2
Large sample test statistic Z	-1.836282
Two-tailed probability	P = 0.0663

Dot-and-Line diagram

The two-tailed probability (P) which is 0.0663 is greater than significance level of 0.05 [0.0663 > 0.05], which means that the researchers have to accept the null hypothesis that the median of the population of the paired differences is zero. This implies that the visual acuity test using iVRead is accurate and acceptable to use.

LIGHT REFLEX TEST DATA

Patient No.	Light Reflex	
	iVRead	Manual
1	1	0
2	0	0
3	0	0
4	0	0
5	0	0
6	0	0
7	0	0
8	1	1
9	0	0
10	0	0
11	1	1
12	0	0
13	0	0
14	1	0
15	0	0

Legend: (1-with Strabismus, 0-without Strabismus)

In light reflex test, the iVRead results is compared in a manual eye misalignment test using ophthalmoscope (welch allyn). The test subjects are instructed to follow the light from ophthalmoscope and the doctors will determine whether there is a presence of strabismus. The assigned values 1 for patients identified “with strabismus” and 0 for “without strabismus”. Based from the 15 samples, the probability of matched is copared with the z value. Using the z-test for proportions, for an alpha of 0.05, the critical z value is 1.96.

Matched:	13
Total samples:	15
Probability:	0.3711
Zo:	0.894

Using the p-value approach: The p-value is $p = 0.3711$, and since $p = 0.3711 \geq 0.05$, it is concluded that the null hypothesis is not rehected. Therefore, the population mean iVRead results is equal to the Clinical results.

REFRACTIVE ERROR DETECTION DATA

Sample No.	Refractive error					
	iVRead			Autorefractor		
	SPH	CYL	AX	SPH	CYL	AX
	(D)		(°)	(D)		(°)
1	-1.50	-1.50	48	-2.00	-1.50	9
2	-0.25	-0.50	173	0.00	-0.25	145
3	-0.25	-0.75	171	0.25	-0.75	173
4	-2.25	-0.50	50	-3.00	-0.75	0
5	-2.00	-0.75	84	-2.25	-0.50	94
6	-0.75	-0.75	158	-1.00	-0.50	176
7	-0.75	0.00	133	-0.50	-0.50	27
8	-0.25	-4.00	30	0.00	-4.25	1
9	-0.50	-1.25	133	0.00	-1.25	179
10	-3.25	-1.50	121	3.25	-1.50	171
11	-0.75	-0.50	47	-1.00	-0.75	11
12	0.00	0.00	55	-0.25	-0.25	72
13	-4.00	-1.50	23	-5.00	-1.50	8
14	-3.75	-1.00	8	-3.75	-1.25	4
15	-0.75	-3.00	15	-0.75	-3.25	8
16	-1.50	-1.50	42	-1.75	-1.75	178
17	-0.25	-0.50	172	-0.25	-0.25	173
18	-0.25	-0.75	164	0.25	-0.75	173
19	0.00	-0.50	176	0.00	-0.50	173
20	-2.00	-0.75	84	-2.00	-0.75	80
21	-0.75	-0.75	156	-1.00	-0.50	163
22	-0.25	0.00	125	0.00	-0.50	175
23	-0.75	-2.75	31	-0.75	-3.00	6
24	0.00	-2.25	49	0.25	-2.25	3
25	-3.00	-1.00	10	3.25	-1.25	1
26	-1.00	-1.00	10	-1.00	-1.00	7
27	-0.75	-0.50	124	-0.75	-0.25	54
28	-4.25	-1.75	33	-5.00	-1.75	23
29	-4.50	-2.00	8	-4.25	-2.00	9
30	-2.25	-3.25	10	-2.25	-3.25	7

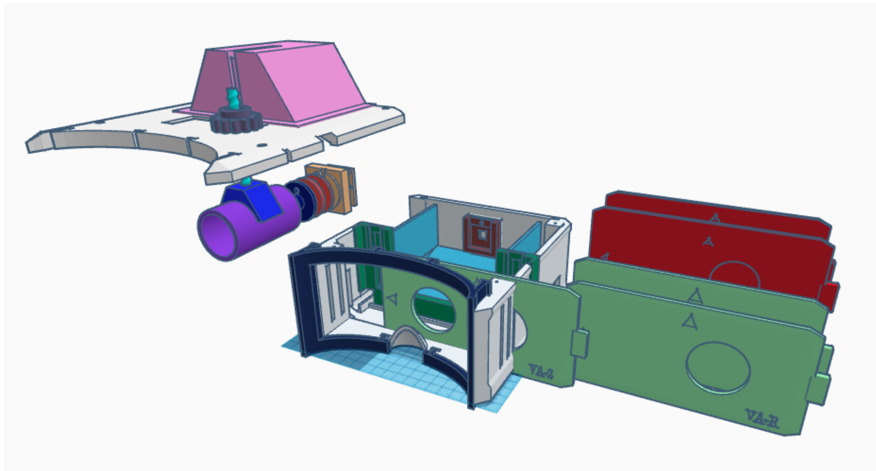
As for refractive error detection, paired sample t-test is used to compare the results from the clinical autorefractor to the iVRead device. The lower aberration of the eyes contains three refractive components such as sphere, cylinder, and axis. SPH and CYL is in diopters and AX is in degrees.

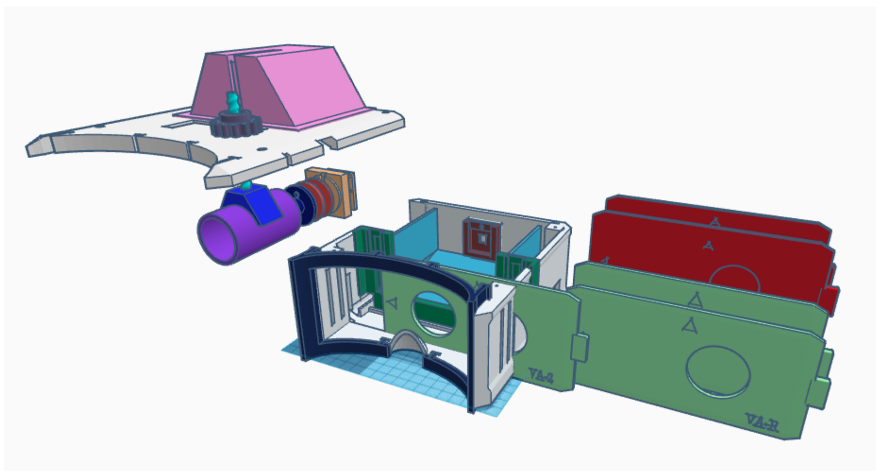
	SPH		CYL		AX	
	iVRead	***Autorefractor***	***iVRead***	***Autorefractor***	***iVRead***	***Autorefractor***
Mean	-1.416666667	-1.041666667	-1.225	-1.283333333	81.43333333	76.76666667
Variance	1.92816092	3.694324713	0.988577586	1.067816092	3808.667816	5870.667816
Observations	30	30	30	30	30	30
Pearson Correlation	0.530258721		0.978333558		0.833378053	
Hypothesized Mean Difference	0		0		0	
df	29		29		29	
t Stat	-1.229227243		1.488908551		0.602806765	
P(T<=t) one-tail	0.114433745		0.073653433		0.2756613	
t Critical one-tail	1.699127027		1.699127027		1.699127027	
P(T<=t) two-tail	**0.228867491**		**0.147306866**		**0.5513226**	
t Critical two-tail	2.045229642		2.045229642		2.045229642	

The p-values of SPH, CYL and AXS are 0.2289, 0.1473, and 0.5513 respectively. Since the following p-values are all greater than the significance value of 0.05, this proves that the population mean difference is zero, thus there is no significant difference between the iVRead results and autorefractor results.

APPENDIX F

Project Documentation

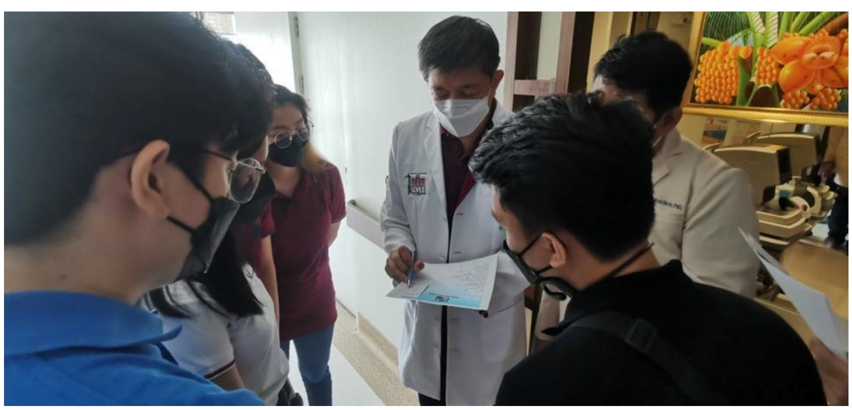




3D designing iVRead device using Tinkercad

Front view of the iVRead device

Side view of the iVRead device



Pilot Testing at Manila Doctors Hospital

Clinical Testing at Santos Cllinic in Malabon

Project Deployment

APPENDIX G

Researcher's Profile

Jonalaine P. Aporado

10 Kaunlaran St., Muzon, Malabon City
09519113520
jonalaine.aporado@tup.edu.ph

Personal Information

Birthday: December 10, 1999
Age: 22
Height: 162 cm
Weight: 48 kg
Citizenship: Filipino

Personal Skills

- Has good oral and written communication
- Knowledgeable in electronics theories and concepts
- Proficient in Microsoft Office software such as:
  - MS Word
  - MS PowerPoint
  - MS Excel
- Oriented in programming languages such as:
  - Python
  - R programming
  - Matlab
  - R

Career Objective

To obtain valuable experience, knowledge, and skills that will enable me to use and enhance my ability in the field of engineering. Work with passion and seek a responsible for the goodness of the organization.

Educational Attainment

Tertiary: *Technological University of the Philippines - Manila*
Bachelor of Science in Electronics Engineering Ayala Blvd. Ermita, Manila AY: 2018 – Present

Secondary: *Malabon National High School*
Naval St., Malabon, Metro Manila
SY: 2016 – 2018

Malabon National High School
Naval St., Malabon, Metro Manila
SY: 2012 – 2016

Primary: *Muzon Elementary School*
Katipunan St., Malabon City
SY: 2006 – 2012

Seminars

Google I/O Extended Manila 2022
Google Developer Groups, July 30, 2022

Data Literacy Fundamentals
DataCamp, April 14, 2022

5G Evolution: The Path to 6G
Terra Hertz Pilipinas Inc., March 13, 2022

Organization Affiliations

Organization of Electronics Engineering Students (OECES)
Member (2018 – Present)

Institute of Electronics Engineering Students of the Philippines
Member (2018 – Present)

TUP ECE Graduating Class Documentation
Committee (2021 - Present)

Google Developers Students Club (GDSC-TUPM)
Innovation Research Core Member (2021 - Present)

Cloie Jed Allen L. Ciria

567 Kadiwa St. San Antonio Cavite City, Cavite
09392328006
cja.ciria@gmail.com

Personal Information

Birthday: May 26, 2000
Age: 21
Height: 5’3’’
Weight: 51 kg
Citizenship: Filipino

Personal Skills

- Knowledgeable in concepts of CISCO
- Knowledgeable in electronic theories
- Knowledgeable in Microsoft Office:
    - MS Word
    - MS PowerPoint
    - MS Excel
- Oriented in programming languages:
    - Python
    - R Programming
    - Octave
- Good in oral and written communication

Career Objective

To be collaborative, motivated fresh graduate honed on pressured environment. Well-versed in project implementation, computer networking, analytical thinking and creative problem solving. Passion for learning and development on self-improvement skills.

Educational Attainment

Tertiary: *Technological University of the Philippines - Manila*
Bachelor of Science in Electronics Engineering Ayala Blvd. Ermita, Manila AY: 2018 – Present

Secondary: *Cavite National High School*
Martin St. Caridad, Cavite City, Cavite
SY: 2016 – 2018

Cavite National High School
Martin St. Caridad, Cavite City, Cavite
SY: 2012 – 2016

Primary: *Julian Felipe Elementary School*
M. Gregorio St. San Antonio, Cavite City, Cavite
SY: 2006-2012

Seminars

SEMICON: Unravelling Limitless Solutions to Infinite Advanced Technologies
Host/Organizer, April 26, 2022

Organization Affiliations

Organization of Electronics Engineering Students (OECES)
Member (2018 – 2020)

Institute of Electronics Engineers of the Philippines – Manila Student Chapter (IECEP-MSC)
Member (2018 – 2020)

Paul Vincent D. Custodio

Gen Evangelista, Talaba 4, Bacoor City, Cavite
09212382762
custodio.paulvincent@gmail.com

Personal Information

Birthday: January 7, 1999
Age: 23
Height: 5’5”
Weight: 63kg
Citizenship: Filipino

Personal Skills

- Knowledgeable in electronics theories and concepts
- Has good oral and written communication
- Oriented in Microsoft Office software such as:
  - MS Word
  - MS PowerPoint
  - MS Excel
- Oriented in programming languages such as:
  - Python
  - Java
  - C++
  - R
  - Arduino/Raspberry Pi

Career Objective

“To seek a challenging opportunity where I will be able to utilize my strong organizational skills, educational background, and ability to work well with people which allow me to grow personally and professionally.”

Educational Attainment

Tertiary: *Technological University of the Philippines - Manila*
Bachelor of Science in Electronics Engineering Ayala Blvd. Ermita, Manila AY: 2018 – 2022

Secondary: *Las Piñas National High School-Senior High School*
Daniel Fajardo, Las Piñas City
SY: 2016 – 2018

Las Piñas National High School Main
Daniel Fajardo, Las Piñas City
SY: 2012 – 2016

Primary: *Aniban Central School*
Aniban 2, Bacoor City, Cavite
SY: 2006 - 2012

Seminar/s

SEMICON: Unravelling Limitless Solutions to Infinite Advanced Technologies
Host/Organizer, April 26, 2022

Organization Affiliations

Organization of Electronics Engineering Students (OECES)
Member (2018 – 2022)

Institute of Electronics Engineers of the Philippines – Manila Student Chapter (IECEP-MSC)
Member (2020 – 2022)

DOST-TUP Scholars’ Club
Vice President for External Affairs (2018 - 2022)

Ma. Daniella M. Gallego

Sitio Pasipit St. Brgy. Plaza Aldea Tanay, Rizal
09289751805
espdaniella.gallego@gmail.com

Personal Information

Birthday: September 15, 1999
Age: 22
Height: 5'2"
Weight: 46kg
Citizenship: Filipino

Personal Skills

- Proficient in Cisco Packet Tracer, NI Multisim, and Circuit Wizard.
- Managerial and Leadership Skills.
- Proficient in Microsoft Office applications such as Word, PowerPoint, Excel, etc.
- Handle group of people.
- Handle tasks simultaneously.

Career Objective

To seek an opportunity to develop and enhance my knowledge and experience, personally and professionally in a challenging environment.

Educational Attainment

Tertiary: *Technological University of the Philippines - Manila*
Bachelor of Science in Electronics Engineering
Ayala Blvd. Ermita, Manila AY: 2018 – Present

Secondary: *Technological University of the Philippines - Manila*
Science, Technology Engineering and Mathematics
Ayala Blvd. Ermita, Manila
SY: 2016 – 2018

Easmont School Philippines
Pililla, Rizal
SY: 2012 – 2016

Primary: *Simeon R. Bendana Sr. Memorial Elementary School*
School Address
SY: 2006-2012

Seminars

Completion of Cisco Networking Academy Introduction to Packet Tracer Course
March 17, 2021

Digital fabrication and modeling technologies: an introduction to computer-controlled manufacturing
Institute of Electrical and Electronics Engineers, May 14, 2022

Power On: Amplifying Knowledge and Career Opportunities in the Field of Power Electronics
Organization of Electronics Engineering Students, May 28, 2022

Organization Affiliations

Organization of Electronics Engineering Students (OECES)
Member (2018 – Present)

Institute of Electronics Engineering Students of the Philippines
Member (2018 – Present)

John Rey R. Mangaliman

Sitio Dalig, Brgy. Bunducan, Nasugbu, Batangas
09278216916
johnrey.mangaliman@gmail.com

Personal Information

Birthday: July 9, 1999
Age: 23
Height: 5’8”
Weight: 60kg
Citizenship: Filipino

Personal Skills

- Knowledgeable in electronics theories and concepts
- Has good oral and written communication
- Oriented in Microsoft Office software such as:
  - MS Word
  - MS PowerPoint
  - MS Excel
- Oriented in programming languages such as:
  - Python
  - Java
  - C#
  - R.

Career Objective

“I am seeking opportunities to join a company that can help me in enhancing my skills, strengthening my knowledge, and realizing my potential. I am willing to explore a wide variety of opportunities that can help me gain perspective.”

Educational Attainment

Tertiary: *Technological University of the Philippines - Manila*
Bachelor of Science in Electronics Engineering Ayala Blvd. Ermita, Manila AY: 2018 – Present

Secondary: *Batangas State University ARASOF – Nasugbu* R. Martinez St., Brgy. Bucana, Nasugbu, Batangas
SY: 2016 – 2018

Batangas State University ARASOF - Nasugbu
R. Martinez St., Brgy. Bucana, Nasugbu, Batangas
SY: 2012 – 2016

Primary: *Bunducan Elementary School*
Sitio Centro, Brgy. Bunducan, Nasugbu, Batangas
SY: 2006 - 2012

Seminar/s

SEMICON: Unravelling Limitless Solutions to Infinite Advanced Technologies
Host/Organizer, April 26, 2022

Organization Affiliations

Organization of Electronics Engineering Students (OECES)
Member (2018 – Present)

Institute of Electronics Engineers of the Philippines – Manila Student Chapter (IECEP-MSC)
Member (2018 – Present)

Jonathan Jr. O. Marcelino

#65 P. Oleta Street Brgy. Wawa, Pililla, Rizal
09565146143
jonathanjr.marcelino@gmail.com

Personal Information

Birthday: June 24, 2000
Age: 22
Height: 5’7’’
Weight: 68kg
Citizenship: Filipino

Personal Skills

- Has good oral and written communication
- Knowledgeable in electronics theories and concepts
- Proficient in Microsoft Office software such as:
  - MS Word
  - MS PowerPoint
  - MS Excel
- Oriented in programming languages such as:
  - Python
  - R programming
  - Matlab

Career Objective

To obtain a position in the field of Electronics Engineering, to utilize my technical skills for achieving and developing the best performance in the organization, which allow me to grow personally and professionally.

Educational Attainment

Tertiary: *Technological University of the Philippines - Manila*
Bachelor of Science in Electronics Engineering Ayala Blvd. Ermita, Manila AY: 2018 – Present

Secondary: *University of Rizal System – Morong*
Morong, Rizal
SY: 2016 – 2018

Pililla National High School
**Under Science Technology Engineering Mathematics Program*
M.A. Roxas St. Brgy. Bagumbayan, Pililla, Rizal
SY: 2012 – 2016

Primary: *Primary School Name*
M.A. Roxas St. Brgy. Bagumbayan, Pililla, Rizal
SY: 2006-2012

Seminars

SEMICON: Unravelling Limitless Solutions to Infinite Advanced Technologies
Host/Organizer, April 26, 2022

Organization Affiliations

Organization of Electronics Engineering Students (OECES)
Public Officer (2020-2021)
Member (2018 – Present)

Institute of Electronics Engineering Students of the Philippines
Board of Director (2020-2021)
Member (2018 – Present)