Designing an Application for Pediatric Eye Care in Armenia

An Interactive Qualifying Project Report submitted to the faculty of Worcester Polytechnic Institute in partial fulfillment of the requirements for the Degree of Bachelor of Science in cooperation with The Armenian EyeCare Project. Submitted May 12th, 2021.

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Abstract

Our goal was to create an eye screening tool to decrease preventable blindness cases due to untreated eye dysfunctions. Through collaboration with the Armenian EyeCare Project (AECP), we developed a set of eye tests that enable school nurses and parents to identify whether a child needs to seek further eye treatment. We were able to provide a design of an application user interface as well as a paper version of it until the application is fully developed.

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Executive Summary

The Armenian population has been experiencing a higher than normal rate of eye diseases and dysfunctions within their population. Mainly due to the struggling healthcare system which has been affected in many ways by events such as the country's separation from the Soviet Union, conflicts with surrounding countries, specifically Azerbaijan and Turkey, and the more recent impacts of the COVID-19 pandemic. The best way to combat the increasing epidemic of blindness in Armenia is to detect eye defects early and start treatment as soon as possible. However, the lack of healthcare resources has led to many eye disorders going unnoticed until the damage to the eye has become untreatable, which can eventually lead to blindness.

To address this issue of accessibility throughout the country, the Armenian EyeCare Project has made various efforts to make eye care more attainable. The next steps to making eye care more accessible begin with having a user-friendly eye screening test available to the general population. By creating an eye screening tool that children could use in a school setting, more vision problems could be caught and treated before the condition worsens, which may increase the chances of preventing blindness.

Our goal is to design an eye screening application for smartphones and a corresponding paper version that will serve in place of the application until it can be fully developed. These tools will enable school nurses, teachers, and parents to identify eye defects in children. We expect that our screening application design will decrease the cases of blindness in Armenia by making eye screening more accessible. We plan to achieve this outcome by fulfilling the objectives below:

1. Identify eye diseases appropriate for in-school and at-home screening.
2. Design a wireframe for the eye screening application.
3. Produce a paper version of the eye screening tests.
4. Produce clear and concise instructions for the eye screening tests.

Vision problems in children can affect far more than just their eyesight. Academic performance, social development, and behavioral growth can all be hindered by poor vision. Treating eye diseases early is crucial in allowing a child to develop at the same pace as their peers and grow into a balanced, healthy, and well-adjusted adult life. In-school vision screenings can provide a convenient and cost-effective service for school-aged children. This is particularly important for low-income countries and children residing in remote regions. Though the purpose of in-school screenings is not necessarily to replace professional eye exams, access to vision screenings for these children can help prevent the negative effects of eye diseases and vision impairment (Burnett et al., 2018).

In order to combat the issues seen with the inaccessibility of eye care and the fact that most in-school screening tests are only focused on nearsightedness while there are many other eye dysfunctions that could be affecting school-age children, potential necessary tests for in-school screening were gathered. This includes a symptom questionnaire, and eye screening tests such as depth perception, color vision, eye tracking, eye-teaming, eye focusing, farsightedness, and a nearsightedness test. This allows for a wide range of issues to be screened for and allowed for us to begin developing a paper version of the eye screening test. These are the same tests that have been put into the wireframe design, as a template of what the fully functioning application should look like when developed.

After deciding what tests to use in the eye screening exam, clear instructions had to be written for them that could be understood by a range of people including school nurses or parents of school-age children. As the idea behind the application is to make eye screening as accessible as possible we want to make sure whether the child is being screened in school or at home accurate results are found. We interviewed a number of people, to have them read the instructions and attempt to proctor the screening exam we developed. As a way to test the instructions and the accuracy of the tests and the clarity of their results. Many edits based on the results of these interviews and further consultations with our sponsors in an attempt to make the instructions as user-friendly as possible.

After completing these interviews, our team believes that we have created an optimal set of tests and instructions that would be easy for any parent or school nurse to understand. We accomplished this by using numbered steps for each test's instructions and providing a purpose statement for each test so the reader understands what they need to be looking for when proctoring the eye exam for a child. The test instructions use consistent language and structure so that the test proctor can easily comprehend how each eye test is administered and how to tell if a child has passed or failed each test.

Our recommendations for further development of both the paper-version that was created and the design of the wireframe start with translating both instruction sets to Armenian and conduct another round of interviews with the Armenian instructions. In order for the wireframe design to become fully functioning, we recommend hiring a programmer that will be able to use our base design and integrate all harder to develop aspects of the application the AECP wants. Including creating a database within the application that can keep track of the results of all the users to see if overtime their results when doing the exam have changed and allow doctors to have access to these results, and developing the design into a universal application that can be downloaded on most devices.

Introduction

In recent years, several factors have led to difficulties in healthcare access in Armenia. The country's separation from the Soviet Union led to fewer job opportunities in the country and placed a heavier financial burden on those seeking medical assistance. Along with the recent conflict with Azerbaijan putting a strain on the medical supply chain, as well as managing the ongoing COVID-19 pandemic has taken priority over basic healthcare. These issues have made eye care inaccessible for many Armenian citizens, leading to an increase in preventable blindness cases (Eye Diseases, 2021).With the continued struggles facing Armenia, medical resources are stretched thin.The Armenian population's accessibility to healthcare is a growing issue that needs to be addressed.

The best way to combat the increasing epidemic of blindness in Armenia is to detect eye defects early and start treatment as soon as possible. However, the lack of healthcare resources has led to many eye disorders going unnoticed until the damage to the eye has become untreatable, which can eventually lead to blindness. The morbidity rate concerning eye diseases in Armenia increased two and a half times between 2004 and 2011 despite a slight decrease in the population (Jrbashyan, 2013).

Most vision problems first develop in childhood. In fact, one in four children has an eye disease or refractory error that could result in blindness if untreated (Eye Diseases, 2021). Therefore, it is crucial to begin screening for eye problems at a young age. School-based health services make early eye disease detection screenings accessible to children who would not otherwise be able to make an appointment at a doctor's office. Factors such as location, transportation, time, and financial status, which usually prevent children from receiving an eye exam, are not problems when it comes to health services available at school (Barnett & Allison 2012). Many children spend much of their time at school, so it is easier for them to have a free visit with their school nurse (Barnett & Allison 2012).

To address this issue of accessibility throughout the country, the Armenian EyeCare Project has made various efforts to make eye care more attainable. They have opened five regional eye clinics and a mobile eye clinic, which makes one trip around the country every two years, serving approximately twenty-five thousand Armenians each year (Eye Diseases, 2021). Although these clinics have made progress, there is still much to accomplish to make eye care accessible for the three million citizens of Armenia. The next steps to making eye care more accessible begin with having a user-friendly eye screening test available to the general population. By creating an eye screening tool that children could use in a school setting, more vision problems could be caught and treated before the condition worsens, which may increase the chances of preventing blindness.

Our goal is to design an eye screening application for smartphones and a corresponding paper version that will serve in place of the application until it can be fully developed. These tools will enable school nurses, teachers, and parents to identify eye defects in children. We expect that our screening application design will decrease the cases of blindness in Armenia by making eye screening more accessible. We plan to achieve this outcome by fulfilling the objectives below:

1. Identify eye diseases appropriate for in-school and at-home screening.
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Working with information research and the support of the AECP will help us develop the best possible eye exam that will cause the greatest impact on the current eye care issues facing Armenia. This research will allow us to develop an easy-to-use eye exam that has a much greater potential for catching eye dysfunctions than the eye exams that are currently being performed in schools.

Background

This chapter begins with a brief overview of the urgent need for better eye care in Armenia, exploring the origins for why there are so many problems. Next, we discuss previous and existing measures in the effort to decrease preventable blindness in Armenia. Then, we describe the common eye diseases prevalent in children and the benefits of catching the diseases early on in their progression. We then reflect on the impact on healthy childhood development if eye defects are left undetected and untreated. This chapter concludes with us discussing the existing in-school eye screenings for students and how the current COVID-19 pandemic has affected their operation.

State of Eye Care in Armenia

Despite the conflicts seen in Armenia's extensive history, the people and culture have persisted. The more recent political tension and hostility Armenia has experienced with its neighbors have hindered the development of healthcare within the country. As a result of their struggles with the healthcare system, Armenians have suffered from countless cases of preventable blindness starting from childhood. This is predominantly a consequence of inaccessible eye care for Armenians in rural areas of the country, and several widespread factors that contribute to the desperate need for assistance, including devastating earthquakes and conflict Armenia faces with Azerbaijan and Turkey. Citizens who live with untreated eye diseases, injuries, and blindness resulting from these circumstances will typically have poor health and cannot function to their full capacity.

The beginning of Armenia's strain on its healthcare system began with the dissolution of the Soviet Union and their independence in 1991. Before the dissolution, all healthcare systems in Armenia were Soviet-controlled, with entirely free medical services for all citizens (Hovhannisyan, 2004). Once gaining its independence, Armenia transitioned its economic system from communism to capitalism (Keshishian & Harutyunyan, 2013). Making the change to a capitalist government included measures such as decentralizing health care expenses where individual citizens no longer had access to free medical assistance and were now responsible for their own medical costs (Zopunyan & Quinn, 2013). This new system made healthcare a personal financial responsibility for Armenians and it resulted in less accessible healthcare, which would undermine the eye care efforts beginning just a few years after.

The dissolution of the Soviet Union also led to a massive loss in employment opportunities, causing what is known as a "brain drain," where many of the country's most educated individuals left Armenia to pursue more desirable career opportunities, including optometry (Yerkanian, 2000). The "brain drain" led to an overall decline of healthcare services and put a considerable economic and social strain on the healthcare system, limiting healthcare service access (Hovhannisyan, 2004). The lack of job opportunities combined with the ongoing political tensions between Armenia and Azerbaijan caused a wealth gap in the country and an overall deterioration in the socio-economic state (Von Schoen-Angerer, 2004). The conflict with Azerbaijan also caused issues within Armenia's medical supply chain and increased the financial burden on Armenia. The numerous emergency patients from the war have overshadowed the general healthcare of the Armenian people, eye care included.

Figure 1. The five regional clinics in the provinces of Shirak, Lorri, Tavush, Vayots Dzor, and Syunik (Eye Disease, Armenian EyeCare Project, 2021)

The Armenian EyeCare Project (AECP) began in 1992 and is still working toward eliminating all cases of preventative blindness of Armenia's children and adults (Eye Disease, 2021). The organization is a permanent fixture of clinics and an extensive eye disease research center established in Yerevan, which has allowed for treatment to be available to many Armenians. Their work expanded from their main office in Yerevan to five regional eye clinics spread around the country, as shown in Figure 1. The AECP is still trying to establish programs that bring 21st-century eye care technology throughout the country. The AECP's mission is to make eye care accessible to every adult and child in Armenia. With the hope that the program will eliminate all preventable blindness, this is only possible if eye screening, eye care physicians, and inexpensive materials are available to even the most rural areas.

The AECP's Efforts to Decrease Preventable Blindness

The AECP primarily provides emergency and surgical assistance to patients with eye diseases through their healthcare programs. While this is helping many people, the organization is not yet able to fully meet the growing need for general eye treatments and eye exams. The AECP's programs focus on services that can be categorized in one of their five-point strategies. These five points consist of patient care programs, medical education and training, public education, research, and capacity building. Some of the patient care programs they provide include a corneal transplant program, a diabetes program, a mobile eye hospital, and a prosthetic eyes program (Eye Disease, 2021). Besides patient care treatments, the AECP also focuses on providing medical education and training, including family physician training, an online training program, and telesurgery (Eye Disease, 2021). Telesurgery is a type of surgery that is performed at a distance using medical robots to help the surgeon operate over long distances. Most of the programs they provide are focused on surgical eye treatment, which causes a lack of general eye care and vision check-ups, such as vision testing. These general eye treatments do exist within the AECP, however, their focus is on surgical treatments and teaching, one program they developed for general eye treatment is a children's eye screening program that screens for diseases such as Amblyopia, though there is limited access to these tests for the general Armenian population. Without these general eye treatments, many children will never know they need glasses or any other sort of vision correction, which could cause development and education issues, or a child could have an eye disease that if caught early could be treated and prevent future blindness. There are many other diseases that affect the younger population of Armenians and will be discussed in the following.

Common Eye Diseases and The Benefits of Early Disease Detection

The ability to detect any disease early can be the deciding factor between whether the disease spirals out of control or is kept manageable. This deciding factor holds true for the people of Armenia without easily accessible eye screenings, where a growing number of preventable blindness cases are going untreated. Early vision screening is an essential tool in preventing long-term complications, as clarified in the study *Pediatric Vision Screening* where the authors concluded that "Vision screening assessments in early childhood reduce the risk of vision loss at age 7 years by more than 50%." (Loh & Chiang, 2018). Being able to catch symptoms and treat diseases early is an important area of focus for organizations such as the AECP, which put a lot of effort into producing programs to increase the early disease detection rate. To understand the importance of early disease detection, we must first look into the common eye diseases that are affecting the children of Armenia. Once we know which diseases we face, then we will be able to determine the true impact of early detection.

Though there are many different types of eye defects and disorders, 80% of overall blindness cases, and 70% of childhood blindness cases, are preventable or curable with access to eye screenings and treatments (Eye Disease, 2021). Without early screening, many diseases can go unnoticed and present later in life when they are difficult if not impossible to treat, causing social and developmental hardships down the road. Some of the most common eye issues can be prevented or treated if they are diagnosed early. Most can be treated with corrective lenses, or when found early enough, with simple surgical treatments. The further these diseases progress, the harder they are to treat and the higher the likelihood of future blindness grows.

Amblyopia, or "lazy eye," is one of Armenia's most common eye diseases among children. Amblyopia is a condition that appears in early childhood where one of the eyes has underdeveloped nerves, and the brain favors the other eye, which can further lead to wandering eyes and poor depth perception. The symptoms of amblyopia are not necessarily obvious. Still, most parents can notice if their child is struggling with their depth perception with behaviors such as squinting, using only one eye, or tilting their head to try to see better (National Eye Institute, 2019). According to *Pediatric Vision Screening*, "Amblyopia is more easily and successfully treated the earlier it is detected, and it becomes impossible to treat after 7 to 9 years of age." (Loh & Chiang, 2018). This statement speaks both to the need for early screening and the importance of the AECP's eye screening program for children.

Glaucoma is a disease that causes severe damage to the optic nerve. The optic nerve is responsible for processing visual information from the eye to the brain's visual cortex. Damage to the optic nerve is due to the abnormally high pressure from fluid building up behind the eye's surface and not being able to be released. Some of the symptoms associated with glaucoma include sudden blurry vision, severe eye pain, headaches, nausea, and vomiting (Boyd, 2020). The cause of glaucoma is not precisely known, but it is becoming increasingly prevalent in children, especially in regions such as Armenia. Vision loss due to glaucoma is typically irreversible, which is why regular eye screenings are essential as well as receiving the appropriate treatment to perhaps prevent further damage to the eyes.

Refractive errors are another common eye abnormality in children. Globally, uncorrected refractive errors are responsible for 43% of the world's visual impairment and are the main cause of moderate and severe visual impairment (Eye Disease, 2021). There are three types of refractive errors: astigmatism, hyperopia, and myopia. Astigmatism is when the surface of the eye is not smooth and deviates in curvature. The eye's abnormal shape captures light in various directions resulting in distorted and blurry images. Hyperopia, more commonly known as farsightedness, is a condition where objects at a distance are seen more clearly than those that are close and can be the cause of chronic headaches and painful eye strain. The opposite of hyperopia, myopia or more commonly known as nearsightedness, is when someone can see objects that are close but have a tough time seeing objects that are far away. Myopia is much more life-threatening than that of the other two if medical attention is not sought out immediately. It can cause a condition called retinal detachment where a tear develops in the retina and fluid builds up behind the retina pushing it out of place (Dean McGee Eye Institute, 2021). While the effects of these diseases can be devastating and irreversible, early detection can minimize the damage done by them.

Childhood Development Issues and Eye Disease

Vision problems in children can affect far more than just their eyesight. Academic performance, social development, and behavioral growth can all be hindered by poor vision. Treating eye diseases early is crucial in allowing a child to develop at the same pace as their peers and grow into a balanced, healthy, and well-adjusted to adult life.

The issue of sight problems in children is amplified by the fact that many do not tell their parents, or doctors when they are struggling to see. While children and parents may understand that the child is not performing as well as their peers academically, they will fail to comprehend that the child's eyesight is the problem (Ebeigbe, 2017). Well-intentioned parents will then attribute other possible issues as the cause of these problems, such as a learning disability (Ebeigbe, 2017). While there are some physical signs that a child is having difficulty seeing, such as squinting or moving closer to objects to try to see better, many times this gets overlooked and the child's education and development begins to suffer.

Visual issues in children can have a serious impact on their education if they go untreated. Approximately eighty percent of learning occurs visually for the first twelve years, whether that be on a whiteboard, worksheets, or through a demonstration performed by the instructor (Eye Disease, 2021). If a child is unable to see any of these teaching tools properly, it will be far more difficult to understand the subject matter. A recent study conducted in Spain with over ten thousand elementary school student participants found that children with poor academic standing were over two and a half times more likely to have a visual disorder than their peers (Alvarez-Peregrina, C. et al., 2020). Some students may also look down on their peers who struggle academically, which as discussed above, children with poor eyesight are more likely to underperform in school. These academic challenges cause children to be more frustrated and build a barrier for these children between themselves, their teachers, and their peers as they fall behind.

The social issues which arise in children who have difficulties with their sight can be attributed to many factors. The frustration some students feel with being unable to understand their schoolwork can cause them to lash out at their peers or develop anger management problems. Another large factor in these social issues is that their eyesight limits the activities they can join their peers in for interactive games (Rainey, L., et al, 2016). The inability of children with deteriorated vision to participate in these activities makes it difficult for them to bond with their peers.

Another more pressing issue that arises from childhood blindness in developing countries is that an estimated 60% - 80% of children die within one to two years after becoming blind, due to complications from their eye problems (Eye Disease, 2021). When we consider that eighty percent of childhood eye problems can be treated using corrective lenses, we can greatly reduce the risk to Armenia's youth by providing annual eye checkups for children and offering corrective treatment before their condition becomes more serious (Shakarchi, A., & Collins, M., 2019). The best method for correcting this injustice is to make screenings more accessible in early childhood before their condition escalates to full blindness.

Providing adequate eye care for children younger than eighteen years old proves challenging, as most failed in-school vision screenings go without a follow-up with an optometrist. One survey showed that the main reasons American parents did not follow up a failed eye exam with an appointment were financial struggles and a lack of time to bring their child to an appointment (Kimel L., 2006). This becomes a greater issue in developing countries where time and money are scarce resources for many citizens, showing that accessibility is the main issue facing eye care.

In-School Screenings to Decrease Preventable Blindness in Children

In-school vision screenings can provide a convenient and cost-effective service for school-aged children. This is particularly important for low-income countries and children residing in remote regions. Though the purpose of in-school screenings is not necessarily to replace professional eye exams, access to vision screenings for these children can help prevent the negative effects of eye diseases and vision impairment (Burnett et al., 2018).

Increased accessibility to eye screening exams in schools could lead to the detection of eye issues earlier that could help prevent further problems. Though some eye defects may not be able to be treated, early detection of these issues would benefit the patient in helping them to find resources to help them. The other type of eye issue that screening would not help with would be eye injuries, though these are responsible for a large portion of global blindness, they are not necessarily preventable.

In-school screenings, however, are limited to the most basic screening methods of distance and reading vision tests such as eye chart tests. There are also no guarantees that vision problems will always be correctly identified with these tests. In addition, in-school screening does not require parents to take their child to an eye doctor afterward that can provide the necessary treatment. Even if a test correctly identifies eye issues there is a potential for no corrective outcome due to the inaccessibility, and cost of eye care (Kimel L., 2006).

The Effects COVID-19 on Eye Care

The COVID-19 pandemic has put a strain on healthcare systems all over the world. The increased number of sick people needing treatment, trying to maintain physical distancing, and trying to minimize the number of social interactions to slow the spread of the highly contagious disease are all contributing to the strain. To help healthcare services be able to deal with the large number of people affected by the virus most healthcare facilities have stopped accepting non-emergency visits–anything that is not life-threatening in the current moment is being pushed to later (Argulian, 2020). While healthcare services are not accepting nonurgent patients, schools are also closed or at a limited capacity, negatively affecting the ability to do in-school eye screening.

In March of 2020, the Armenian government shut down all schools in Armenia due to the emerging COVID-19 pandemic (“Armenian Students Offered Distance Learning Opportunity”, 2020). The school shutdowns left many Armenian students without the resources they usually had access to. Resources including the in-school eye screenings that the AECP had previously put in place in various schools across Armenia. The schools reopened in the fall, then quickly shut down again on October 15th due to a sharp increase in COVID-19 cases, with more than two thousand cases a day in Armenia. The schools were set to reopen again in December with tighter restrictions in classroom sizes, strict hygienic rules, and limited resources (“Armenia To Again Reopen Schools”, 2020). The schools being repeatedly opened and then closed again do not allow for accessible in-school screenings.

Closed schools leave children without even an opportunity to have an initial screening to see if they need further treatment with an eye disease or a refractive error. According to the European COVID-19 Cataract Group (EUROCOVAT), ophthalmologists are in the extremely high-risk group for contracting COVID-19 since they come into close contact with their patients for more than fifteen minutes (Toro et al., 2020). These two factors combined can have great consequences for the future of eye care and the health of those who currently do not have access to eye care services.

The emerging alternative to in-person healthcare services is telemedicine services. Telemedicine is different from telesurgery, which provides treatment options that can improve access and provide diagnoses through photographs (Maa et al., 2014). Through recent trials, the results when compared to face-to-face eye exams suggest that telemedicine still provides highly accurate diagnoses and treatment options (Maa et al., 2014). The results of online consultations are often the same as results provided with in-person appointments and will often lead to the same treatment plans. This method was developed to provide access to rural patients but could be adapted or renewed for current times as a remote screening option. While the most prevalent screening options in the telemedicine department are looking for symptoms of eye diseases, they still focus on diseases that need surgical assistance. Developments in telemedicine can be made to shift the focus to more general eye issues, like the need for glasses. These lesser diseases need to be screened for in order to lower the number of children being affected by eye issues and lower the number of preventable blindness eye disease cases in countries such as Armenia.

Summary

Early detection is crucial for minimizing the effects of potentially harmful eye defects. Parents or guardians are not always able to tell when something is wrong with their child's sense of vision, and the children themselves are not able to compare their own eyesight to what it ideally should be. Routine screening for visual problems in children prevents the condition from becoming more serious and allows these children to develop at a steady pace alongside their peers. With early detection, common diseases affecting eye health such as amblyopia, glaucoma, and refractive errors can be properly treated. This preventative treatment will help to manage the number of blindness cases throughout Armenia.

Building off the work already being done by the AECP, our goal is to design an application that would be utilized for the eye screening of children of Armenia. If fully developed and produced, the application would assist school nurses and parents in identifying if a child needs further eye care. Armenian children and parents would benefit the most from the outcome of our project along with the AECP. Although this is only a small step in the direction of eliminating preventable blindness, it would be a huge step for early disease detection in children.

Our application design would make eye screening more accessible so that anyone who has access to a smartphone will be able to take a visual test. This application will be especially useful in areas where healthcare services are scarce. Families will be able to keep track of any issues in their child's vision during stay-at-home emergencies which might normally prevent a child from getting access to an eye exam. The screening test could be proctored by a nurse at school, or by a parent at home, at any time. The information obtained from the screening application can then be used to seek help for children who need treatment. We hope that this increase in accessibility will improve early detection that is so crucial to reducing the long-term burden of eye defects and disorders in Armenia.

Methods

The goal of this project is to help the Armenian EyeCare Project (AECP) combat the increased number of preventable blindness and eye issues seen in Armenia. By designing an application that can be fully developed and used for in-school eye screening, as well as an accompanying paper version for those who do not have access to smartphones, we will increase accessibility to eye screenings throughout the country. This will help identify vision problems early on which is essential in preventable blindness cases. To achieve the goal, we developed the following objectives:

1. Identify eye diseases appropriate for in-school and at-home screening.
2. Design a wireframe for the eye screening application.
3. Produce a paper version of the eye screening tests.
4. Produce clear and concise instructions for the eye screening tests.

These objectives were completed using information researched about the most common eye issues and what kinds of tests can be used to identify them, what is currently being done in schools for eye screening, similar existing applications, and previous research of eye disease testing from specialists including the AECP and the SUNY State College of Optometry. (Figure 2).

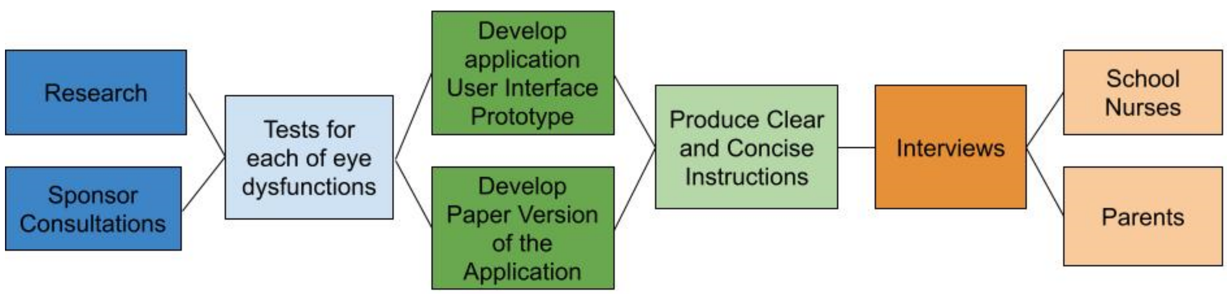


Figure 2. Timeline of Objectives

Objective 1: Identify Eye Problems for In-School and At-Home Screenings

This objective guided us to better understand the range of eye dysfunctions that are appropriate for in-school and at-home screenings in Armenia. By researching the range of eye problems that impact school-aged children in the country, we became confident in the eye conditions to include those that would reach the goals of the application. This information includes general and specific symptom identification and the relevant tests to identify the symptoms of an eye dysfunction. Increasing the availability of eye exams and the range of conditions which they can test aid in identifying eye dysfunctions and gain invaluable data for the AECP.

Currently, most in-school eye screenings only include screening to identify nearsightedness. Only testing for one eye disease fails to identify an extensive range of diseases and eye abnormalities that many children have. This lack of range highlights a critical problem with the eye screenings in place, which is why there is a need for a more comprehensive screening. The application will allow parents of children who have eye problems other than nearsightedness to know if they need to seek professional care from an optometrist or other specialist. Through this objective, we researched the most effective eye tests that help identify if a child needs further consultation with an eye doctor.

Our team held consultations with our sponsors and conducted interviews with school nurses and parents of school-aged children. Because of the language barrier and high potential of misunderstanding, the project team, the sponsors, and the advisors agreed that interviewing Americans would produce optimal results. From previous information from our sponsors, our team has gathered that our application needed to include screenings for nearsightedness, farsightedness, color blindness, depth perception, eye teaming, and eye-tracking. They helped us build the outline for what tests needed to be included, while the school nurses and parents of school-aged children helped us understand how to effectively communicate the instructions of how to administer the tests. They also assisted us in understanding some of the standard testing protocols for eye screenings. This information further allowed us to see the current issues with the system, such as the eye exams not meeting the needs of the children. It also gave us an idea of what issues and symptoms are the most prevalent and which ones can be easily tested for.

Objective 2: Design a Wireframe for an Application

The design of our application is user-friendly and clearly demonstrates how the application moves through testing for the various eye defects. It also details how the test results can be recorded and accessed. The wireframe, which is a user interface blueprint, can be understood by any parent or nurse which enables them to properly interact with the final product to proctor an eye exam for a child. A programmer is also able to understand what needs to be coded so the application can run the tests as designed. The wireframe details how the user interface functions and how the database should store test results.

The most important factor in designing a user-friendly application is understanding what is intuitive for parents and children when they interact with it. It is assumed that the users of this eye screening tool have basic knowledge when it comes to technology and smartphone use as the technology is essentially an everyday-use item. Therefore, it was important to ensure that every user understood what they needed to do so each test is given the same way. The design of the application is also careful as to not distract from the eye exam so the children taking the tests are able to focus on the task at hand. This leads to the best results, which allow for the most accurate reflection of a child's performance on the exam.

There are two key steps to achieving these results in our design. First, we used a combination of medical research and research into user interfaces to develop the first draft of our prototype. We applied the findings from our research to create a low-fidelity wireframe of the application, which was used while improving our design. A low-fidelity design of an application would typically be a simple model composed of paper sketches that are meant to imitate the fully developed application. The unpolished appearance allows changes to be made with ease by altering the sketches and conveys the general ideas of the product to anyone interacting with the model.

We continued improving our design through interviews with parents and school nurses. The group of interviewees were adults who represent the possible ages of school nurses or parents of a young child. The interviewees interacted with our low-fidelity prototype of the application during a recorded session and provided us with feedback on the design. During these interviews, we asked interviewees to perform various tasks using the prototype as if it were a real smartphone application. Once they are done interacting with the prototype, we asked our interviewees for design feedback to adjust our prototype for another round of testing based on any problems which arose from the interviews. Our participating interviewees ranged in their technical ability to reflect the target demographic of parents and nurses who would be helping children to take the eye exam.

By observing how our volunteers interacted with a prototype, we were able to study their reactions to the design of the application and better understand how they will interact with a finished application. Recording these interviews allowed us to analyze the details of an interview and read the interviewee's body language for any confusion. The recordings also kept a record of each interaction and enabled our team to review any small details, feedback which we received, as well as notice any common themes. Whether an interviewee performs all tasks correctly is the most important element of conducting an effective eye screening exam, and we want to eliminate any potential confusion a user might experience. For example, if we ask a participant to perform a certain task and their finger goes to press one button on the interface, then they hesitate and change direction, we will be able to identify that the function of the two buttons is not immediately clear to the volunteer. Using a low-fidelity prototype allows participants to visualize a functioning application, but the lack of a finalized, polished look will encourage them to give honest feedback since it is clear the application is still in the early design phase, during which changes are easy to implement. Whether an interviewee performs all tasks correctly is the most important element of conducting an effective eye screening exam, but we aim to eliminate any potential confusion a user might experience.

There are, however, some challenges facing this interviewing strategy. For the health and safety of all project members and interview participants, we were not able to conduct interviews in person due to the ongoing COVID-19 pandemic. Therefore, a low-fidelity prototype made from sheets of paper would be impractical for our interviews. This meant that we needed to develop a virtual prototype for participants to interact with during a recorded video call. There is also a language barrier between the project group and the Armenian citizens who would be the users of this application. This language barrier limited our group to only be able to interview those who speak English. Gathering this information over Zoom presented itself as challenging, so we planned to record the interview sessions so they can be reviewed as needed, though only notes from the interviews were taken as an alternative to recording the whole session.

Objective 3: Produce a Paper Version of the Tests to be Included

A paper version of the eye screening test includes a version of all the tests that will be available on the application in the future. In a way, this paper version of the eye screening test is a prototype for the actual usage and results of the application. The purpose of this is to test out the eye screening methods, making sure the tests are easy to use, correctly identify if there is an eye problem, and making sure the tests are focused on the correct issues. This paper version of the test is a comprehensive set of instructions on how to perform multiple different eye exams, and questions based on the potential symptoms of eye dysfunctions in order to identify if the participant has eye dysfunctions and should consult an optometrist for further diagnosis and treatment methods.

Using this objective as a prototype for the application can help to understand how it will be used in schools. This understanding will be based upon the accuracy of the results, and how easy it is for the tests to be performed. The new tests are a combination of existing tests for the most common eye dysfunctions as eye care is already a very well-researched and developed topic. However, what does not exist is an easy-to-use all-encompassing test that can be performed in schools, which is playing a part in the increased number of preventable blindness and eye issue cases in Armenia. Mainly this test focuses on the most common eye issues, including near and distance sight acuities, color blindness, and stereopsis testing. These eye issues are what are currently being tested for in schools in the United States based on information from the SUNY State College of Optometry and their developed screening exams. According to the AECP, these are also the issues that are prevalent in Armenia and need to be diagnosed to help the children with eye issues. The data that were collected using their past research and what was collected during interviews from both the SUNY State College of Optometry and the AECP on the best ways to do eye screening tests were used to develop this objective of creating a usable paper test.

Having a comprehensive exam that provides testing on multiple different eye issues at once helps to increase the availability of eye testing. This is because it will be much easier to perform in school which will increase the rate of early eye screening. This increase directly aids in decreasing the possibility of eye diseases progressing and causing vision impairment or blindness. Using the information on current tests being used that were developed by the SUNY State College of Optometry, a test like this can increase the number of children being referred to an eye doctor by the school, more clearly identifying children with eye dysfunctions. Most schools, outside of the ones that have adopted the SUNY eye screening tests, only test for distance and miss out on testing for other diseases causing many individuals with eye problems to go unnoticed.

Some of the same challenges will still exist even with an easy in-school screening tool. This tool still requires parents to take their child to the eye doctor to seek out treatment for the eye issues that may be found. Adding to this issue would be the accessibility of an eye doctor. If it is too difficult to take the child to see an eye doctor, there might be no real results from the eye screening tests. While this is and will always be a challenge, especially based on the health services availability, the increased potential for eye diseases to be found early could still positively affect Armenia's growing issue of preventable blindness. This, like the application tests, could potentially also produce a false positive and negative. The likelihood of this happening can be decreased through extensive testing to make sure this eye exam is producing the most accurate results. Another current issue regarding eye care is the COVID-19 pandemic which has led to closed schools and limited access to medical resources. As a result, it might not be an option to perform vision tests on all students. Therefore, the goal is that the developed test will be easy to use and able to be performed by parents at home in order to identify if their child needs further consultation with an eye doctor.

Objective 4: Produce Clear and Concise Instructions

The purpose of this objective is to produce clear and concise instructions for the users of our test. The two foremost reasons to produce clear and concise instructions revolve around the test user's interaction with our test. The first and most obvious one is the fact that we needed instructions for how to set up and administer the tests. For example, the common eye chart poster featuring lines of letters that become increasingly smaller would be useless if it was administered by simply handing a paper to someone and asking them to read the letters in each row. To get accurate results from a test like this, there needs to be a set distance at which the participants read off the letters row by row, each getting increasingly smaller in size. The other reason we needed these clear and concise instructions is to reduce confusion and be more straightforward. If we distribute a functioning eye test with confusing instructions, it is more likely that the test will be performed incorrectly. This would lower the accuracy of the test making it unreliable. Without these instructions, the test may be performed in various ways which would lead to incorrect or conflicting results.

One of the primary questions that we had to accomplish this objective is, what are the assumptions we are and are not allowed to make. Different parts of the world will assume and interpret the same instructions differently due to different perspectives and cultural mindsets. Therefore, to produce clear and concise instructions we needed to know our specific audience. We also researched what other types of instructions work or don't work. The basic types being referred to are written instruction versus audio/spoken instruction versus pictured instructions. This information and research aided us in compiling the most appropriate and useful set of instructions for the tests that we produce.

There are two primary ways in which we achieved this goal. The first will be to reference instructions for similar tests. For this data collection strategy, we individually read through instructions for existing eye exams. This involved trying many different types of tests. We attempted to follow the written steps ourselves and took note of any questions or concerns we may have had while taking the vision test.

This strategy allowed us to analyze confusing language versus effective language when it comes to writing instructions for an eye exam. Our team took note of any trends that fell into either category and used this insight to advise our own writing in each iteration of the instructions. We used the information gathered from this process as a starting point with which to create the first iteration of our own instructions.

After creating our initial set of instructions, we refined them by interviewing volunteers who represented a similar demographic of users that would be administering this test for a child. Since the average Armenian is not fluent in English, we were instructed by our sponsors to interview Americans in the same roles as our intended audience. The intended audience is school nurses and parents of school-aged children. These interviews were conducted through a video call and notes were taken for later review. Interviews allowed us to assess and improve our writing in order to produce a set of instructions that are increasingly tailored to the end-users of the product. We had the users attempt to use the prototype instructions to administer the tests and wrote down any concerns or questions they may have had. We also asked the participants to talk out loud about their thoughts while working through the instructions.

After each interview, we addressed any issues or questions that were identified by participant feedback. To make the data received from the interviews and self-tests quantifiable, we classified the types of questions being asked and marked how many times one of our instruction steps is asked about within a certain number of interviews. For example, if we had a set of instructions that are five steps long and we received a question on step three from half of our interviewees, then we would conclude that the step does not contain clear information. We would also classify the questions through coding the interviews to determine where the step is lacking. If there are enough questions, then it could warrant the addition of another step or the removal of a confusing or contradictory step. An example of the self-test form of research would involve similar steps that we would answer ourselves. If we ask too many questions about a certain step in a test, then we rephrase the step. The combination of these two analysis methods gave us both quantitative and qualitative data.

Our methods relied on designing, testing, and continuously creating improved versions until the result is a clear set of instructions for our end-users. It was imperative to include the end-user in this process because without them, it is likely that they would overlook many nuances of the process which would inhibit our goal. It is also important to include the framework of successful previous works in the area of at-home screening to combine and consolidate the strengths of many different types of instructions as mentioned above.

Although we strived to produce clear and concise instructions, there are inherent challenges as not everyone will interpret everything the same way. It is infeasible to make changes according to every comment received in an interview as some comments we are given may contradict others. Although there are multiple opportunities for errors to propagate, the process we took aimed to minimize the number of total errors. Regardless of the language, if a step in our set of instructions gets many questions, then it needs improvement, the issue would only arise when updating a step, which can hopefully be caught in the following cycle of interviews.

Results

This chapter will present the findings we found throughout completing this project, organized based on the methods used for data collection shown in the previous chapter. Starting with information researched on the issues with current in-school and at-home screening. Then discussing both versions of the screening exam that were developed. The design of the wireframe for the application and how the paper-version of the test was developed. Finally, in this chapter, we will discuss the findings of the interviews and how they impacted the creation of the user-friendly instructions used in both the wireframe design and the paper version.

Objective 1: Identify Eye Problems for In-School and At-Home Screenings

Using the research questions posed in the methods we were able to identify the issues with the current state of eye screening and compile a set of tests that will detect most of the eye problems that are affecting the children of Armenia. Using the knowledge that primarily what is being done for in-school screening is only focused on nearsightedness which only catches a fraction of the children with eye defects combined with research that shows what else are the most common eye defects the following list of tests were developed.

A symptom questionnaire was written for a basic test to see if the child is experiencing any side effects of the most common eye diseases. After this baseline symptom questionnaire, the screening moves on to depth perception, color vision, eye tracking, eye-teaming, eye focusing, and distance/visual acuity tests. These tests were specifically chosen because they are designed to catch the greatest amount of eye defects in the children being screened. Using all these tests will decrease the number of children that experience difficulty in educational development due to having one or more of these eye defects. Our questionnaire was developed based on consultations with our sponsors, members of the AECP, and members of the SUNY College of Optometry who provided us with information about what the children should be able to see as a baseline along with research done on the subject.

Consultations with the sponsors helped us to modify some of the tests that we found while researching and making sure all the tests developed were found to be child-friendly. For example, the distance reading test uses shapes as opposed to letters to allow very young kids with undeveloped reading skills to do the test and the color vision test focuses more on red-green colorblindness which is more commonly found in children. Consultations also revealed that certain commonly used eye tests might not be the easiest to perform, give the best results, or even be practical to perform. For example, the Hirschberg test is an eye teaming test, where the tester shines a light into the patient’s eye and the patient looks at the light while the tester compares the location of the patient's pupils. According to our sponsor, there are many issues with this test including the negative effects of staring into a light for an extended period of time, and there is a large source of error in seeing if the pupils are lined up this way since it is not easy to identify especially if an expert is not performing the test. After the consultation, this test was changed to a more accurate and simpler version.

Through the research and consultations we did, our original idea that the in-school screenings are lacking and failing to catch a significant amount of eye defects was confirmed with further insight into what could potentially be done.As well as the opportunity to use in-school and at-home screening as a way to help with issues with educational development that are caused by eye defects and as a way to decrease the cases of preventable blindness. Supported by the fact that we were able to gather tests and develop them for a large range of possible eye dysfunctions.

Further understanding the potential of eye screening in the in-school and at-home setting will directly help school nurses and parents of school-age children. This understanding and development of tests will provide them with a broad baseline eye screening exam that will be easy to perform on school-age children. This will also help the AECP with their overall goal of stopping cases of preventable blindness in the country.

Objective 2: Design a Wireframe for an Application

A wireframe was developed by iteratively testing with a simulation of the application for potential users. As we were unable to program the application, the wireframe was designed through the use of Figma.com. This resource allowed us to design what the individual pages could look like and allow us to share the wireframe with the sponsor. The resource also helps to show how the user may interact with a developed application by permitting the tester to click on buttons within the individual pages to navigate throughout the application.

The pages within the design consisted of a login page, a navigation page, an about page, a symptom tracker, seven test pages, and seven instruction pages. The seven test pages are the same seven tests from the paper version in the following section. The seven instruction pages display the same instructions from the paper version except for the focusing test. For the focusing test, there is no far target to focus on, this target is replaced by a point in the room 3m or 10ft away. Some aspects of the application that can not be shown but are important are as follows. The tests run sequentially from one initial test but also allow for specific tests to be selected when needed. The order of the tests starts with the symptom tracker and follows with distance vision, reading vision, eye teaming, depth perception, eye focusing, eye tracking, and finally color vision. For the color vision test, it was determined that the best implementation would be to run the Enchroma color vision test with shapes within a browser within the application.

The iterations of the application shed light on the difficulty in determining a user interface that is able to work for people with various backgrounds. There were few occasions where there would be conflicting results on the same action which would then lead to a redesign and retest of the action which then would allow for refinement. The user interface tests done should be continued through the development process to refine the functionality of the design.

Objective 3: Produce a Paper Version of the Tests to be Included

To produce the paper version of the tests, we first had to gather all of the appropriate tests to test each of the dysfunctions – distance, eye teaming, depth perception, eye focusing, eye tracking, and color vision. The intent of the paper version is to stand as a prototype for the development of the application and as an alternative to it when technology is inaccessible. It is essential that the tests on the paper version can be reproduced to be on the application and have the same effect. This wider set of eye dysfunctions to be tested for will improve the current state of eye screening. The tests can be seen in figure 3, with the exception of the eye-teaming test since it does not have a visual component in the paper version. Corresponding instructions for each of the tests were developed with the intention of continuously improving them with comments and suggestions given from interviews. Our sponsors suggested that the instructions need to be clear, concise, and easily understood in English first to be effectively translated into Armenian for use in Armenia.

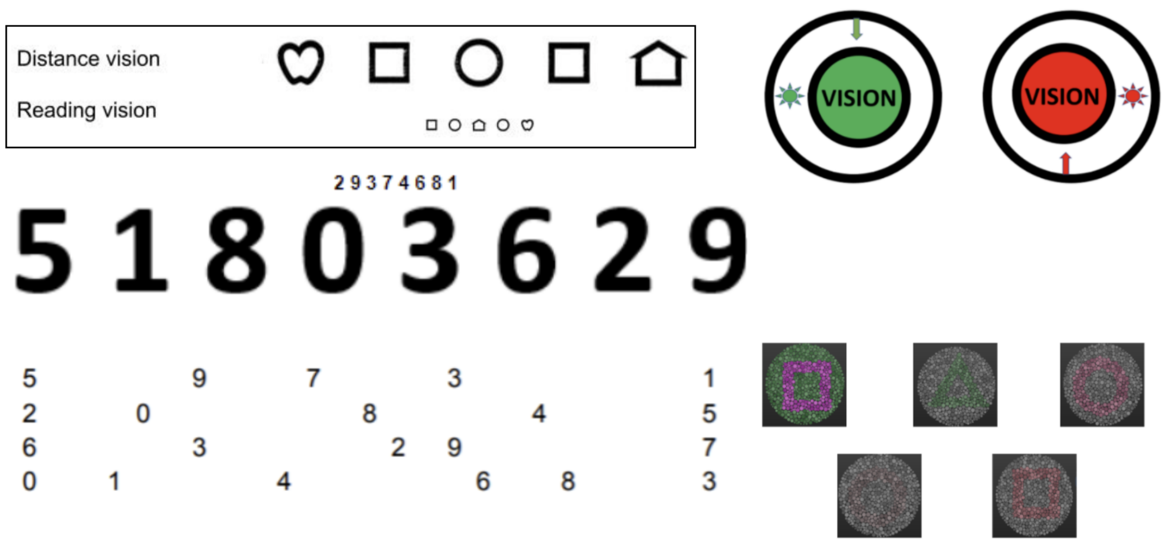


Figure 3. The vision tests used in both the application wireframe and paper version

All of the tests included in the paper version are designed to be passed or failed, there is no in-between level or spectrum to measure. This was at the request of our sponsor in order to simplify the test and make it exceptionally clear whether further eye treatment would need to be taken. This means that if the patient taking the test fails any part of the exam, that is enough cause for the patient to seek further consultation with an optometrist. To account for a possible false positive, which would suggest a patient seek further treatment, error margins are included in each of the tests. These can account for honest mistakes, human error, misspeaks, and overlooked components of any of the tests. These error margins prevent a slew of people from seeking treatment with an optometrist for a problem that does not actually exist.

Ideally, the AECP will use and distribute the paper version of the tests to be used by school nurses and parents for at-home use. The paper version will be what is used until the application can be fully programmed and developed as well as a permanent solution. Since the paper version will be much easier to access and tests for multiple eye dysfunctions, this breaks down the barrier of inaccessibility and will effectively identify if a child has an eye dysfunction. Therefore, this will decrease the number of undetected eye dysfunctions and decrease the impact eye problems have on educational development.

Objective 4: Produce Clear and Concise Instructions

When producing our written instructions for each eye test, the biggest challenge we faced was to figure out the best way to communicate the correct testing procedure so that a parent or school nurse could easily understand and replicate it. Additionally, we need to clear;y communicate the goal of each test so that accurate test results are recorded by the test proctor. To approach this issue, our team decided to create the first draft of instructions by referencing language and writing styles used in written directions for existing eye tests and relying on our own logic to convey the correct information for our specific eye tests.

While researching similar eye tests, our team found that the instructions would commonly establish a set of vocabulary and maintain consistent wording rather than using synonyms. For example, if the person taking the test is called the "subject," this word should be used to identify them every time, rather than using alternatives such as "participant." Our project team followed suit and established a set of vocabulary to use consistently throughout all of the tests to avoid confusing the reader.

Another key element in our written directions is the use of a numbered, step-by-step structure. This format allows our team to convey the correct instructions in smaller parts that are easier for a reader to comprehend. The list of numbered steps provides structure, making the process less intimidating for a guardian or school nurse who might be administering these eye tests to a child. It is crucial that the instructions for the eye tests are not intimidating for the proctor so that they remain calm and comfortable when performing the tests. A proctor who feels confused or overwhelmed by the testing process is more likely to make mistakes, and less likely to want to perform the test again when the child is due for another exam. For this reason, we aimed to make each step in the instructions as concise as possible. We also minimized the number of steps included in each set of instructions.

In order to refine our initial set of instructions, we conducted a series of interviews with adult volunteers. In these interviews, our main source of criticism came from the verbal comments made by the participants. However, the facial expressions, body language, and hesitations the participants displayed throughout the interview were also useful in helping us understand when a participant was confused. For example, someone reading an instruction out loud and then slowing down in confusion to try to figure out what is being asked. Before they had even asked any questions, we already knew from their actions that the particular instruction needed to be made more clear. Through these interviews, we were able to fix confusing wording and we were able to better understand when an instruction was too long and was causing hesitation.

As our team expected, participants were generally comfortable with the small set of vocabulary and seemed to gain confidence with the keywords throughout the course of the interview. Once an interviewee became familiar with the language used in the instructions, they could generally read through the later sets of instructions more quickly. The numbered list of steps also seemed to be a useful structure for participants, as many times they would pause briefly after reading one step and give verbal confirmation of understanding such as “okay” or “got it.” This format also allowed for a participant to stop after reading a step in the instructions to make a comment or ask a question and then easily resume reading where they had left off. This ability is especially useful for parents or guardians who may have to briefly pause reading the eye test instructions to speak with their child or attend to their child’s needs.

One element which we did not expect to affect the clarity of the tests as greatly as it did was the number of steps in a set of instructions. Our team created the instructions with the goal of being as concise as possible, however, we found that even a difference of eight steps and eleven steps in a set of instructions was significant enough to cause some of the readers to feel overwhelmed.

Having clear and concise instructions for each eye test is crucial to anyone who might proctor our eye exam for a child. These proctors will generally be parents or guardians, as well as school nurses. Having instructions that are easy to understand means that the guardian or nurse who proctors the exam can do so quickly and with greater accuracy. Accuracy is the most crucial element in the testing process, as accurate testing leads to more children with eye dysfunctions receiving the eye care that they need. With clear and concise instructions in our eye tests, we can help parents and nurses identify vision issues early enough to take preventative action.

Recommendations

Although this project is intended to be used in Armenia, the members of our project group only speak English. This means that the instruction set for the eye exam used in both the paper version and wireframe design had to be written in English. This created a language barrier which prevented us from interviewing Armenian citizens. Instead, we decided to exclusively interview Americans to eliminate any confusion a language barrier or differing cultures might create from our tests. For further development, we recommend translating all of the instructions into Armenian and conducting follow-up interviews with Armenian citizens to address any issues that may have come up during translation. We would also recommend removing the imperial units included in the instructions, and leaving only their metric counterparts to make the writing more concise.

Our team believes that this eye exam could be used to screen for eye dysfunctions in children all over the world, as long as the exam is translated appropriately and interviews are conducted to ensure the translated version is easy to understand for parents, guardians, and school nurses. We would also suggest that any country which does not use Arabic numbers adjust the eye focusing test to use their own number system. For any parent that wishes to use this eye exam, we recommend that they keep the exam and proctor a test for their children every year. Childrens' visions develop and change greatly as they grow, so it is important for every parent to check regularly that their child's eyesight is developing properly. If a child passes every test one year, that does not guarantee they will be able to pass the exam the following year. Therefore, a parent or guardian should not assume that this eye exam is a one-time test. We also recommend that this test is not proctored to the same child too often, for example, every week or every month. If this test is overused, the child may memorize the answers because they do not want to fail the test.

Our group would also recommend continuing the work of this project by developing a phone application based on the wireframe which we have created. The content in the wireframe should be converted into code which can then be navigated as demonstrated in the wireframe. The backend programming structure also needs to be developed and integrated. This structure should contain a database of users such that each user can sign into the application and record all of their test results. This will not only allow the AECP to follow up with individuals who may need further treatment but also allow them to collect data on the different defects throughout the country and their prevalence. Users should also be able to share test results with their child's doctor or another medical professional. These tasks would be fit for either a mobile application developer or a team of computer science students as a final project.

Conclusion

Though changes need to be made to the paper version of our tests and further development is necessary for the wireframe to become a user-friendly, functioning application, our progress on this project will nonetheless help to decrease the effects of child eye defects that Armenia has recently experienced. Our project will help increase the accessibility of a user-friendly eye screening exam, resulting in an increase in early detection. This will help prevent the effects of eye dysfunctions such as the progression of an unidentified issue which can result in permanent vision loss or educational development issues resulting from the child's visual impairment. A parent or a school nurse should be able to use our work to test for a number of eye dysfunctions that could be affecting a child. Using our project should allow testing to be done easily and inform parents of when to seek further treatment and diagnosis options for their children. Our tool has the potential to save a child from struggling throughout their school experience and prevent them from falling behind their peers which can drastically affect their further education, social skills, and mental health. We would be completely changing the overall state of eye screenings from a simple nearsightedness test only performed in schools to an all-encompassing eye screening exam that can be performed both in schools and at home by any capable adult. With simple translation modifications, our paper-version and the application, when fully developed, have the potential to be used universally. By having all school-age children take the same baseline screening test, we would catch a drastically higher quantity of eye dysfunctions compared to the simple nearsightedness test.

Appendix

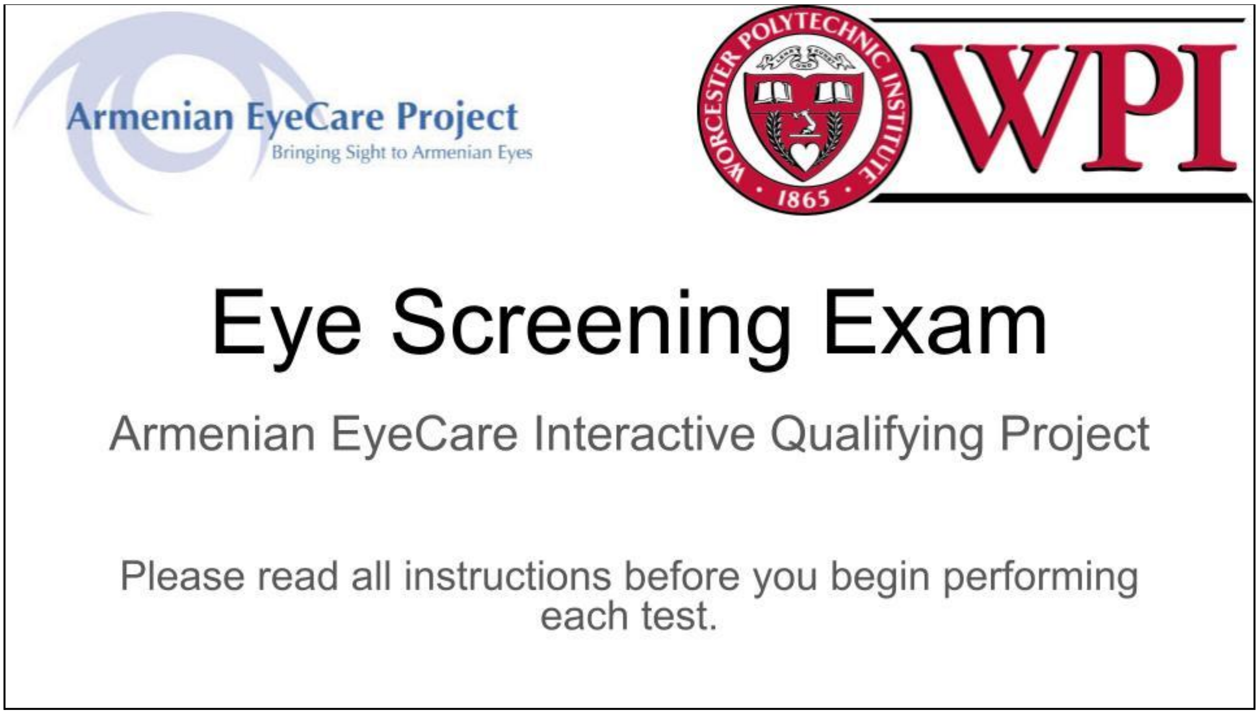


Figure A1. Eye Screening Exam Title Page

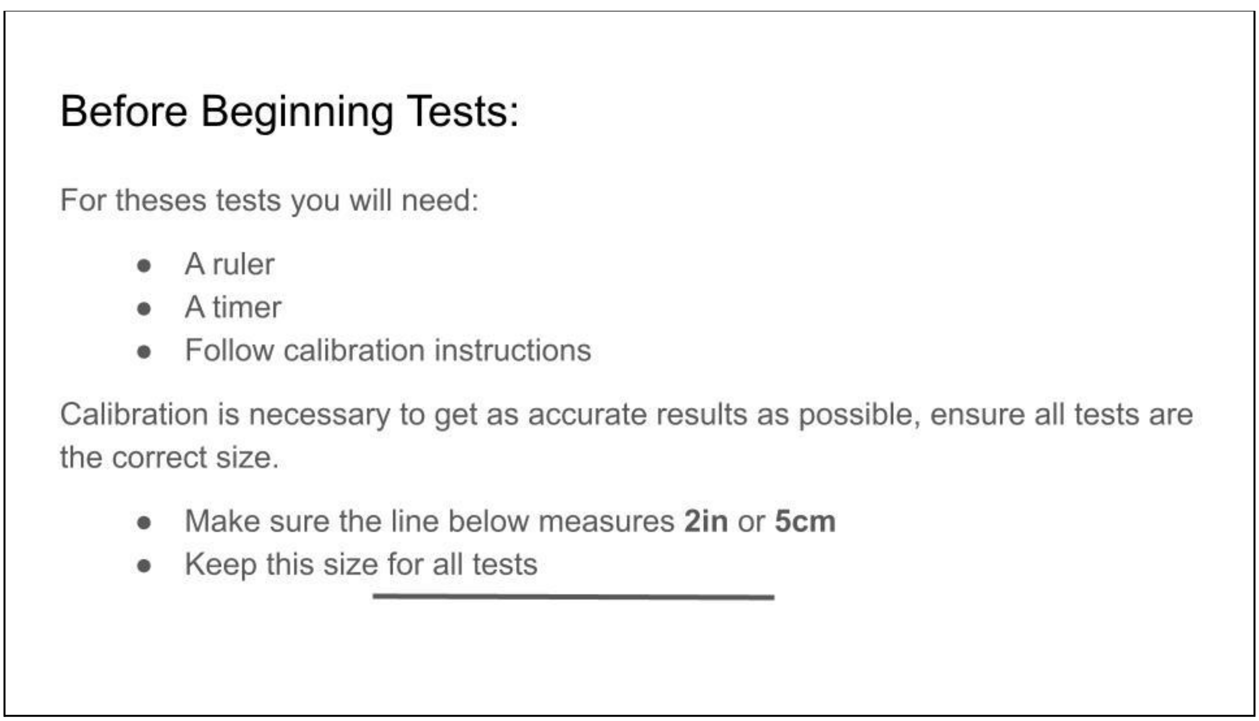


Figure A2. Calibration Slide

Symptom tracker

Purpose: to catch potential eye issues based on factors within school life

Circle 1 if symptom does occur and 0 if symptom does not occur
A score of 3 or above. Seek further treatment options

0/1 Blurry vision at a distance (difficulty reading the board during class)
0/1 Blurry vision close up
0/1 Poor school performance
0/1 Difficulty in understanding/remembering what was read
0/1 Skipping words/lines
0/1 Frequently re-reading
0/1 Headaches/ eye strain when reading
0/1 Letter/number reversal
0/1 Words move on the page
0/1 Double vision
0/1 Difficulty with math
0/1 Eye burning/irritation

Figure A3. Symptom Tracker

Distance Vision

Purpose: This test is for visual acuity at a distance greater than **3m** or **10ft**

1. Place the chart **3m** or **10ft** away from the participant
2. Patient covers their left eye and read the smallest line of shapes the patient can see from left to right
3. Patient covers their right eye and read the smallest line of shapes the patient can see from right to left
4. With both eyes open read the smallest line of shapes the patient can see from left to right
5. *The participant **passes** if they have no more than one mistake identifying the shapes, otherwise they **fail***

Size Scaling Chart

Distance (feet)	70	60	50	40	30	20	15	10	7	4
Distance(meters)	21	18	15	12	9	6	4.5	3	2	1
letter ht (mm)	31	27	22	18	13	9	7	4	3	2

Shapes to be Identified Key:

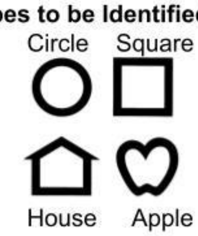


Figure A4. Distance Vision Instructions

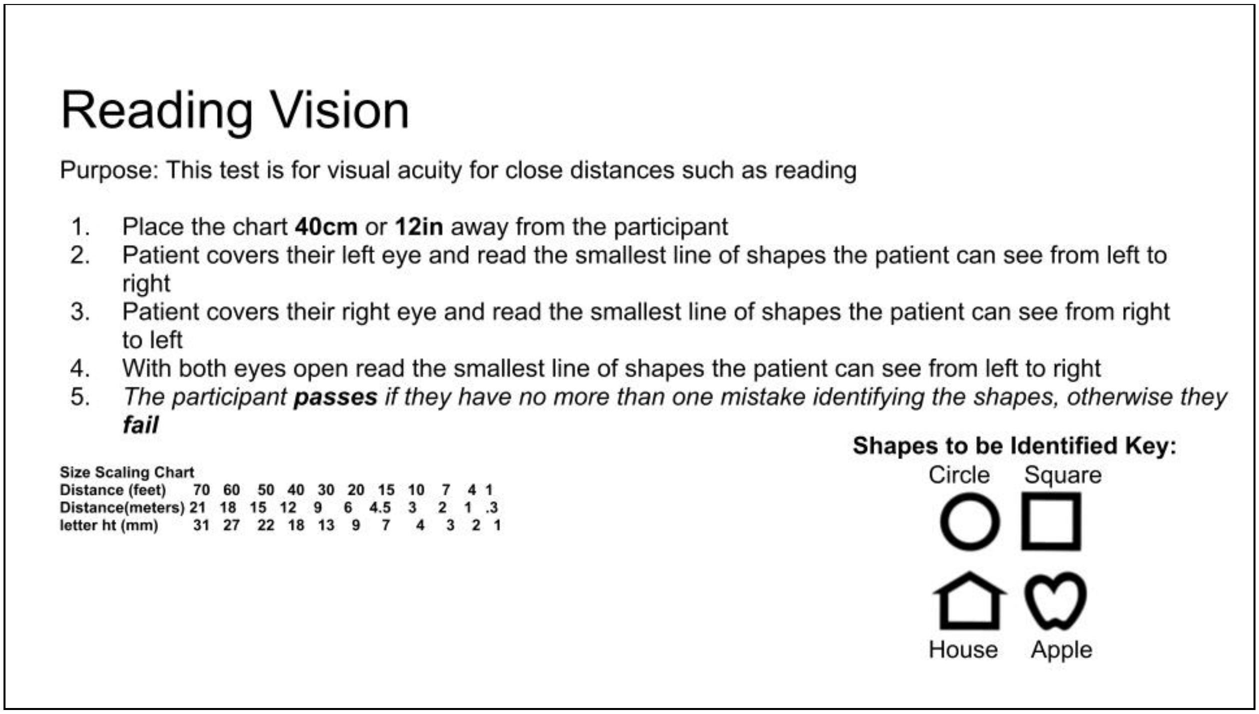


Figure A5. Reading Vision Instructions

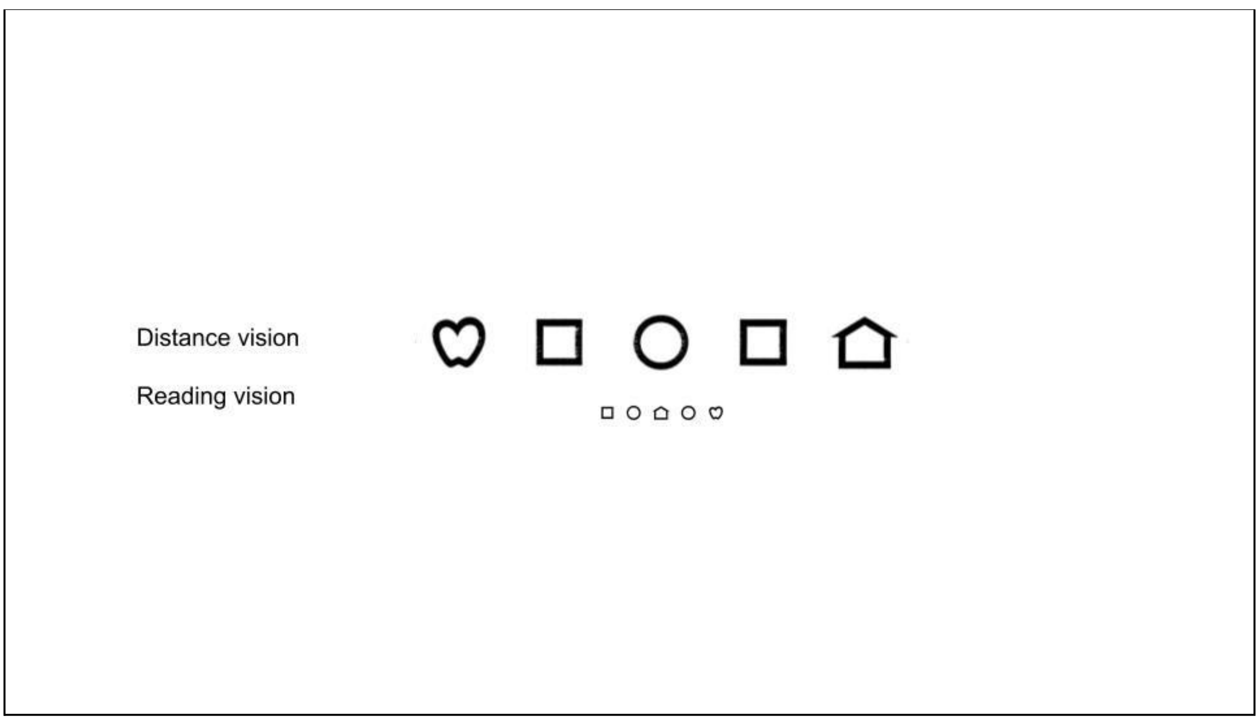


Figure A6. Distance Vision and Reading Vision Tests

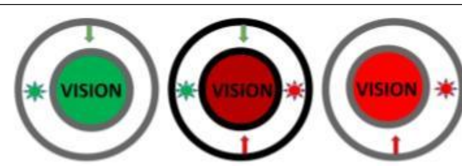
Eye-Teaming

Purpose: To test that both eyes are working together, resulting in sustained, single, and comfortable vision.

1. Take a pen, pencil, or similar object in size in shape
2. Hold the object so that the tip of the pen is about **20cm** or **8in** from the participant's face and aligned between their eyes
3. Ask the participant to tell you when they start to see double
4. Slowly move the object towards their face and watch the eyes closely to see if one eye drifts outwards
5. Stop when the participant says they are seeing double, or when the pen is approximately **7cm** or **3in** away from the participant's face
6. *The participant **passes** if they are seeing one object with both eyes pointing towards the object at **7cm** or **3in,** they **fail** if they see double or if one eye drifts outward*

Figure A7. Eye-Teaming Instructions

Depth Perception



Purpose: To test how both eye work together to produce three dimensional images.

1. Hold device **0.5m** or **18in** away from the participant's face
2. Participant crosses their eyes to see the two circles overlapping in the middle
3. *The participant **passes** if they see the circles overlapping, continue if the circles do not overlap*

If the participant is having difficulty crossing eyes have the participant,

1. Place finger or pen directly in front of image
2. Participant focuses on their finger
3. Have them slowly bring their finger closer to face while staying focused on the finger
4. *The participant **passes** if they see the circles overlapping, otherwise they **fail***

Figure A8. Depth Perception Instructions

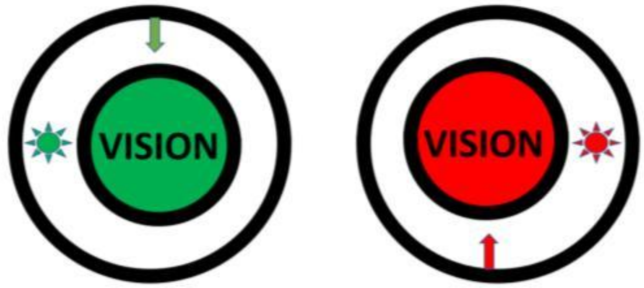


Figure A9. Depth Perception Test

Eye Focusing

Purpose: To test how well the eyes move and work together.

1. Participant to holds the first set of numbers at a reading distance (about **40cm** or **12in**)
2. Hold the second, larger set of numbers about **3m** or **10ft** from the participant
    - Cover all but one of the numbers and ask the participant if they can see it clearly. If there is some blurriness, take a small step closer until they can see the number. Uncover the remaining numbers
3. Ask the participant to read **their** set of numbers aloud, moving from **left to right**
4. Ask the participant to read **your** set of numbers aloud in order from **left to right**
5. Ask the participant to read **their** set of numbers aloud in order from **right to left** (backwards)
6. Ask the participant to read **your** set of numbers aloud in order from **right to left** (backwards)
7. Repeat steps 4-7 one more time
8. Ask the following questions to the participant and take note of their answers
    - Did it get harder to read the numbers?
    - Did you notice your vision becoming blurry as you kept reading the numbers?
    - Do you feel dizzy or like you have a headache?
9. *The participant has* ***passed*** *this test if all of the following is true:*
    - They answered no to all of the questions above
    - You did not notice them struggling to adjust between the distances
    - The difficulty of the test did not seem to increase for the participant over time
    - The participant had no more than 3 errors

Figure A10. Eye Focusing Instructions

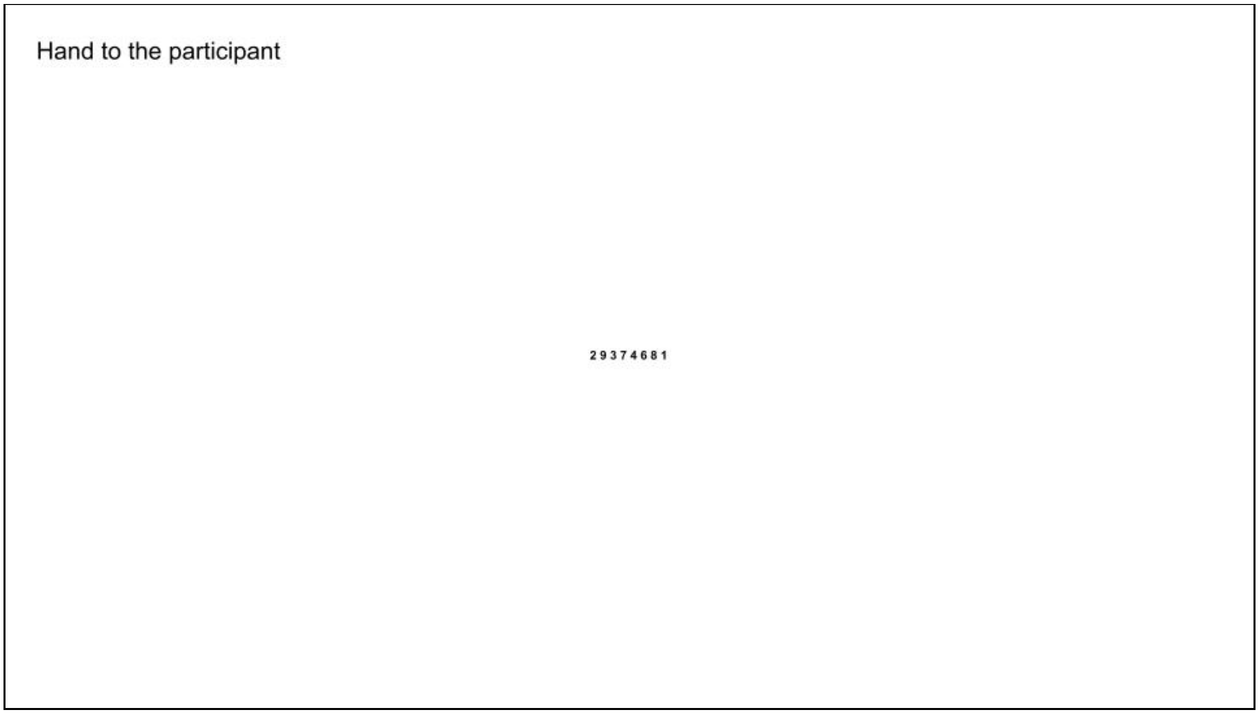


Figure A11. Eye Focusing Test (Near)

Figure A12. Eye Focusing Test (Far)

Eye-Tracking *Timer Required*

Purpose: To test the movement of the eyes when doing activities such as reading.

1. Participant reads the numbers in each line from left to right from **40cm** or **12in** away as quickly as possible, but without making any errors
2. Record the time the participant takes to complete the test
3. Record number of errors
   - Misspeaks on numbers are recorded as errors only if they are not immediately corrected before going on to the next number
4. *The participant **passes** if they complete the test within 30 seconds and with no more than 2 errors, otherwise they **fail***

Figure A13. Eye-Tracking Instructions

10 - 12 pt font

5			9		7			3				1
2		0				8				4		5
6			3				2	9				7
0	1			4					6		8	3

Figure A14. Eye-Tracking Test

Color Vision

Purpose: To test for colorblindness.

1. Participant reads off the 5 shapes seen within the dot pattern
    - If the participant can not verbally identify the shape they can trace the shape or draw the shape in the air and that would still be a correct answer
2. Give about 5 seconds for the participant to answer for each image
3. Compare the participant’s answers with the answer key below
4. *The participant **passes** is if they correctly answer at least 4 out of 5 correct without significant struggling, otherwise they **fail***

Answers:
Row 1: Square, Triangle, Circle
Row 2: Circle, Square

Figure A15. Color Vision Instructions

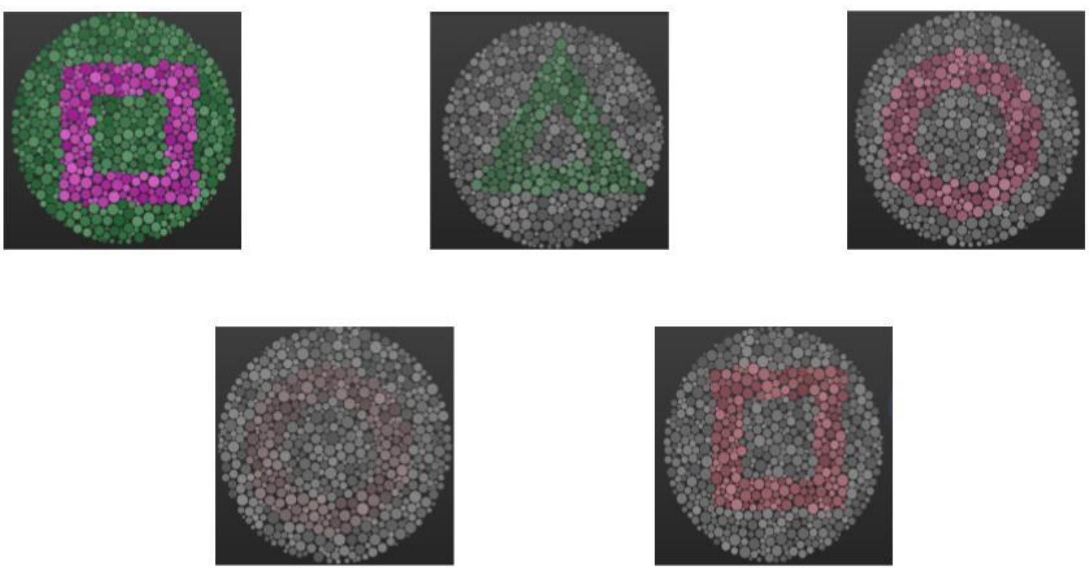


Figure A16. Colorvision Test

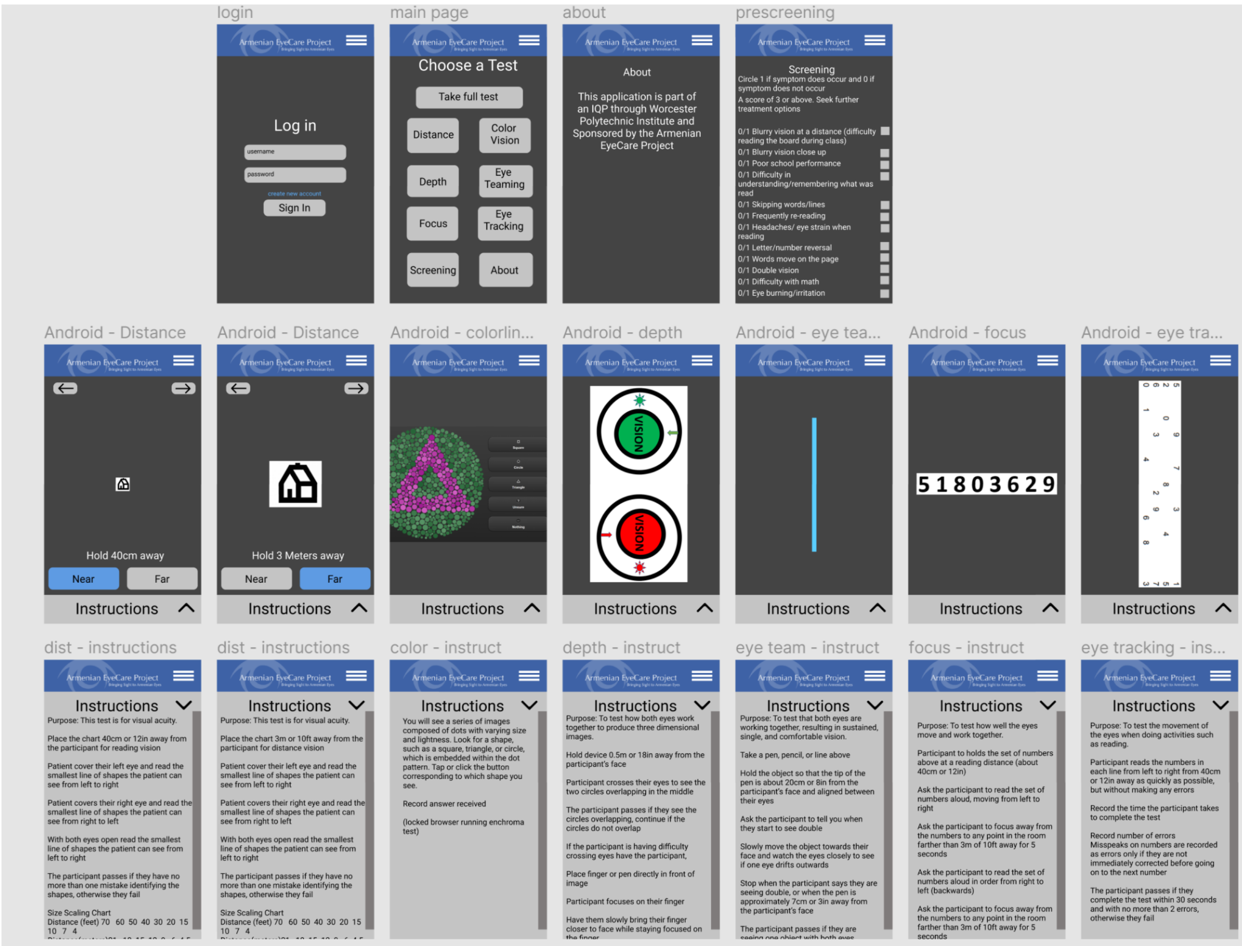


Figure A17. Wireframe Design

Link to wireframe:

https://www.figma.com/file/nx6LFWcJ8tJFQedGlk4Mkw/eye-screening?node-id=0%3A1

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