OptiCare: A Mobile Application Diagnosing Ocular Diseases through Novel Point of Care Methods Utilizing Machine Learning Technology

Over 2.2 billion people worldwide suffer from vision problems, and at least 1 billion of these individuals' impairments could have been prevented with the proper care (*Vision Impairment and Blindness*, n.d.). The main barriers to ophthalmology include economic inequities, limited transportation options, and a lack of eye-care providers in rural areas (Ervin et al., 2022). Two major eye diseases that are common causes of blindness or severe vision loss that remain undiagnosed are cataracts and glaucoma. With around 68% of cataract cases going undiagnosed (Chua et al., 2017) and over 50% of glaucoma cases (CDC, 2021), the inaccessibility of eye care is a leading cause of preventable vision loss and blindness due to the lack of cheap, accurate, and accessible eye care. OptiCare aims to solve the problem of preventable vision loss problem and improve accessibility to reliable diagnostic tools for the potential detection of glaucoma and cataracts.

Cataracts: The #1 Most Common Cause of Blindness

Over 65.2 million people suffer from cataracts worldwide, and this ocular disease is the leading cause of blindness. ⅓ of all cases of blindness are due to cataracts. Cataracts are an ocular disease that occurs when an individual's eye's natural lens becomes cloudy over time. Treating cataracts early can help prevent severe vision loss. Therefore, an early diagnosis is needed to improve an individual's quality of life. Yet, an early diagnosis is easier said than done. There are no early symptoms of cataracts, which makes catching this disease in its early stages difficult. To catch cataracts early, testing for cataracts should be done at least once every year (*Cataracts*, n.d.). Cataracts can be diagnosed through numerous strategies, including simply observing the patient's eye up close. Overall, the diagnosing of cataracts has immense potential to be implemented in a point-of-care system, with the use of cheap but accurate instruments, and will be used for this project.

Glaucoma: The #2 Most Common Cause of Blindness

Glaucoma is another ocular disease that affects around 80 million people worldwide currently. This number is expected to increase to 110 million people by 2040. Glaucoma is caused by a build of intraocular pressure (IOP) in the eye and is the second leading cause of blindness. Glaucoma is 6 to 9 times more common in people of African descent than in other ethnicities and constant testing needs to be done to catch glaucoma early. An early diagnosis of glaucoma can halt and prevent severe vision loss in the future. However, just like cataracts, diagnosing glaucoma in its early stages is a difficult task due to the lack of early symptoms. By the time symptoms of glaucoma start showing up, it is often too late to prevent severe vision loss. To prevent vision loss, frequent eye exams once every 6-12 months should be conducted (MD, 2018). The main tools used to diagnose glaucoma are a fundus camera and a tonometer. A fundus camera can take a picture of an individual's retina, optic nerve head, macula, retinal blood vessels, choroid, and vitreous (*Glaucoma | National Eye Institute*, n.d.). The cost of a fundus camera can range from $9,000-$34,000, but point-of-care alternatives have also been created. As stated in the paper, "Do it yourself smartphone fundus camera – DIYretCAM" a fundus imager can be created using a mobile phone, 20D lens, and PVC pipe (Raju et al., 2016). However, the at-home fundus cameras have one fatal flaw: the lack of dilation in the eye. The dilation of an eye is when the black center of an individual's eye is larger than normal. To dilate eyes, dilation drops can be taken. However, it is important to note that dilation drops can only be administered by a professional. Dilation drops are not available over the counter, and therefore cannot be used in a point-of-care situation. With a lack of eye dilation when taking fundus images, the accuracy and clarity of the images decrease drastically. As seen in the previous study "Undilated versus dilated monoscopic smartphone-based fundus photography for optic nerve head evaluation", only 74% of the tested eyes were possible for smartphone-based fundus imagery when undilated, versus the 98% of eyes that were possible for fundus images after dilation. As a result, it can be inferred that smartphone fundus photography alone is not a viable solution for a complete diagnosis of glaucoma in a point-of-care system (Wintergerst et al., 2018). In addition, mobile tonometry has not been very successful in the past either. A tonometer is an instrument used to measure the pressure in an individual's eye and average prices for a handheld tonometer are $3,000. The previous study "Smartphone Tonometer Effective in Measuring IOP" tried improving the accessibility and decreasing the price of tonometers by creating a point-of-care version, however, it unfortunately performed poorly. The corresponding machine-learning algorithm only successfully processed 56.8% of the inputs (*Smartphone Tonometer Effective in Measuring Iop*, 2020). As a result, there are no accurate and cheap tonometer tools in a point-of-care setting and an improved piece of novel technology must be created for this project.

Novel Technology for the Measuring of Intraocular Pressure

While mobile tonometry uses a traditional applanator and the model remains inaccurate, a more novel approach to measuring IOP is evolving and can be implemented in a point-of-care setting. This is the idea of using sound waves to measure IOP. As stated in the paper, "Testing the Viability of Measuring Intraocular Pressure Using Soundwaves from a Smartphone", there is a relationship between internal pressure and the acoustic the decibels returned in a reflection wave. To explain this idea in more detail, when sound waves are emitted at a specific angle and hit the eye, a portion of the sound waves are absorbed, and the remaining portion of the sound waves are reflected off the eye at the same angle they were reflected on. This paper proves the relationship between pressure and the reflection waves and describes using the measurement of sound waves as a potential route for future work. By utilizing the relationship between pressure and sound waves through the integration of a mobile phone, novel instruments can be created to measure intraocular pressure accurately and cost-effectively in a point-of-care setting (Soanes et al., 2021).

Diagnostic Methods Based on Physical Testing

After all physical tests (fundus images, slit lamp tests, and intraocular pressure measurements) are taken, they are then analyzed for diagnosis. While diagnosis is usually done with the assistance of an ophthalmologist, autonomous diagnosis has made giant leaps in the world of healthcare in recent years. Autonomous diagnostics can be done through the aid of machine learning technology. Machine learning is a branch of artificial intelligence that uses data and algorithms to imitate the learning process (*What Is Machine Learning and How Does It Work?*, n.d.). Starting with cataracts, the slit lamp test is used to observe the opacity of the lens. If the lens is showing signs of opacity, then this may indicate early signs of cataracts. With this relationship in mind, a machine-learning algorithm can be developed to detect and diagnose cataracts using slit lamp images taken from a user's phone. Moving on to glaucoma, another machine-learning model can be created to diagnose glaucoma based on fundus images. Glaucoma can be seen in fundus images when cupping is present. Cupping is the idea of an increased cup-to-disc vertical ratio. However, as mentioned before, smartphone fundus images taken on non-dilated eyes do not provide enough data for an accurate diagnosis of glaucoma. Therefore, in addition to taking fundus images, IOP can also be measured periodically using the novel sound waves incorporated in the assistive tool created as a part of this project and recorded over time in a local digital database to monitor potential increases in IOP. After these models and algorithms are created, they will be implemented in a mobile application to increase accessibility. When published on the App Store, OptiCare will be available to 1.46 billion active Apple users worldwide (Shewale, 2024).

Necessary Resources and Knowledge Required for Diagnostic Models

Specific software and machine learning theory are necessary to create machine learning models and a mobile application. One popular are Neural Networks. Neural Networks are a form of machine learning, in specific deep learning, that works like the human brain: there are numerous neurons that relate to one another to perform tasks, create algorithms, and make prediction (What Are Neural Networks?, n.d.). A few popular options include the integrated development environment (IDE) Google Colab and the programming language Python for machine learning models, the IDE XCode for mobile app development, the programming language Swift for mobile app development, and the user database Core Data.