Design of a Mobile Application for Eye Signs Screening

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Abstract: Advances in technology make mobile phones very attractive to everyone, specially smartphones, with a large number of applications. In this paper we describe the necessary features of a mobile application for eye signs screening, describing some of the ocular pathologies that can be detected with a photograph using a smartphone, and the data collection protocol necessary to obtain this data and later process it. A first version of the developed application and some results are also presented. This application is simple to use, since the main target are the parents, who can use it at home as a tool to trace the visual health of their children, given that an ophthalmologist follow-up is scarce or nonexistent in many places.

1 INTRODUCTION

Currently, the use of mobile applications has experienced a substantial growth, becoming part of day-to-day life of many people. With the increasing use of smartphones several applications in different areas are being developed, including the medical field (J. Chhablani, 2012), (Bethke, 2010). This can make the difference achieving an early diagnosis and, consequently, a higher probability that the disease does not progress to an advanced stage, also in remote places, or with lack of experts (Gallagher, 2013), (Today, 2011). Ophthalmic and optometric organizations recommend a visit to an eye care professional every 1-2 years to have a comprehensive eye exam (Vela et al., 2012). In this paper we propose to develop a mobile application for certain ocular pathologies detection with adequate image collection protocol. The ”Red Reflex Test” (RRT), also named ”Brückner Test’, was considered as an effective form of blindness prevention and early diagnosis of serious diseases such as retinoblastoma, Coats’ disease, anisometropia or strabismus (P.J. Magalhes, 2009), (AAOP et al., 2008), (Amitava et al., 2010).

The motivation for this work arose from several news around the world about parents who post photos of their children on social networks, with some friends noticing that something may be wrong with their vision (Mail, 2007), (Tvi24, 2014), (Stampler, 2014), (JornalNotícias, 2014), (Anne, 2013). A correct diagnosis was made when parents went to an ophthalmologist, who actually detected an eye problem/disease, what led us to the development of an application, which will be presented next.

2 EYE PATHOLOGIES AND OPHTHAMOLOGIC TESTS

In order to design a tool for eye signs screening in a smartphone, it is important to understand the different clinical tests and eye pathologies, since we need to clarify the technological needs, and define an adequate data collection protocol. After reviewing this information, a clinical test feasible for the application in a smartphone was designed. The test and corresponding most common pathologies will be presented in the following sections. This application is meant to be used in detecting common eye pathologies of children, and therefore the data collection protocol must be simple to be practical in this context.

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2.1 Eye Pathologies

A brief overview of the pathologies detectable using the camera of a smartphone will be given in this section. The features that may be useful in the detection of these pathologies will also be described.

2.1.1 Retinoblastoma

Retinoblastoma is a tumor that originates from immature retinoblasts in the neural retina and it is the most frequent intraocular tumor in children, being responsible for 11% of cancer cases in the first year of life. The most common signs of retinoblastoma are: leukocoria, strabismus and inflammatory signs (Ramasubramanian and Shields, 2012). Leukocoria is an abnormal (white) reflex when a direct light source reaches the eye. Because retina is highly vascularized and has red-orange color the light reflected toward the eye must have a reddish appearance, but in this disease there is a change in some internal structure of the eyeball so this reflex is absent, and there is usually a whitish reflection. An algorithm may be envisioned to detect the white spot in the eye of the children, by taking a series of photos. The specialists recommend parents to take photos once a month, in a room with soft light and without red-eye reduction, to check for a normal red-eye reflex in children under six years of age (Fund, 2010). Coats' disease, as well as leukocoria, may be detected in photographs taken with flash, but in this case the eye presents a yellowish color (J. Liebmann-Smith, 2010).

2.1.2 Amblyopia

Amblyopia is another visual impairment that may be detected with the RRT or Brückner test, which is very helpful to detect amblyogenic disorders (Gräf, 2010). This disease is normally called ”lazy eye” because the major symptom is a decrease in visual acuity in a normal eye (Miller et al., 1995). Causes of amblyopia, which is a major cause of vision loss in children and even adults, include strabismus, refractive errors and ocular misalignment (Miller et al., 1995), (Alhammouri et al., 2011), that is why it is very important to detect amblyogenic factors as early as possible. Like strabismus, amblyopia may be detected in a photo with flash light, if there is a change in red reflex symmetry.

2.1.3 Strabismus

Strabismus is an ocular misalignment (TheRoyalCollegeofOphthalmologists, 2012), where one eye is either constantly or intermittently not directed towards the same point as the other eye when the patient attempts to fixate an object. It usually develops during childhood but can occur at any age. Most cases begin before 6 years of age, being the peak age of onset around 3 years (Rutstein et al., 2011). The exams that are made by an ophthalmologist usually include the ”Hirschberg test”, the ”Cross-over”, and the ”Cover-uncover” test, which reveal latent strabismus (Angart, 2014). The Hirschberg test may be used to determine the type and degree of strabismus using a small penlight and directing it toward the eyes. When the patient is looking at the light, a reflection can be seen on the front surface of the pupil. The reflected point of light will reveal the type and degree of strabismus (Medical, 2011). The cover-uncover test may reveal latent strabismus, ”heterophoria”. A cover (occluder) is placed briefly before the eye that appears to fixate while the patient looks at a small object (E.C. Campos, 2002). Finally, the Cross-over test may reveal latent as well as manifest strabismus. As the name suggests in this test, an occluder is transferred from one eye to the other without interval (E.C. Campos, 2002). This brings the idea to develop features in the application that can be helpful in the diagnosis of strabismus. Such as the other disorders referred before, the application will take a photograph with flash, and then, with an algorithm automatically process the image to detect and evaluate the local of the reflex in the pupil, like in the Hirschberg test. After the tests are done, an algorithm may read and calculate the deviation of the eye relatively to the center of the image.

2.2 Red Reflex Test

The RRT is a screening exam for detecting ocular abnormalities using an ophthalmoscope, that emits light with the appropriate intensity over the pupil of the newborn, even without the use of previous drops (P.J. Magalhes, 2009). This test is performed to evalute the eye condition, helping in the diagnosis of the described pathologies, because the reflection of the incident light produces a reddish and continuous color on healthy eyes, meaning that the main internal structures of the eye (cornea, iris, pupil, lens and retina) are transparent, allowing the light normally to reach the retina. In the presence of an abnormality that obstructs the arrival of light to the retina and its reflection, the light reflex undergoes changes that interfere with their coloration, homogeneity and binocular symmetry (Aguiar et al., 2007). The test should be done early in a child's development, given that it is when the vision progresses, and if the diagnosis is reached later, the likelihood of full recovery is smaller. This test is very important, because how it was seen, allows the detection of a huge part of diseases with high incidence in childhood. Thus, this test was chosen to be reproduced in our application.

3 PROTOCOL DESIGNED FOR DATA COLLECTION

After reviewing the most common pathologies and the clinical tests, determining which clinical signs may be detected using technology available in a smartphone, a protocol for data collection needs to be defined within the application. The protocol is a guideline which encompass all the steps that are made by the user, when handling with the mobile application for data collection. For the development of this protocol we had to take into account the light environment, which must be low in order not to allow the pupil to close; the positioning of the person from the subject to not obfuscate their vision; and all the necessary information shown in the screen, so the person fulfill the minimum requirements for the photographs to become perceptibles. The material necessary to do it is a mobile phone with the application installed. The data collection protocol was designed as follows:

1. Create a soft light environment: turning the lights down and ensuring that any light sources - such as table lamps or television - are behind the person (so they dont reflect in the eyes).
2. Position yourself about 3 meters from the child/person and use the zoom to capture the subject's entire head (Figure 1).

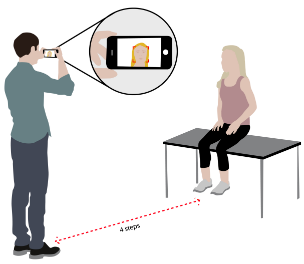

Figure 1: Sketch ilustrating the positioning of the person.

3. Press the button when ready to initiate the collection.
   (a) The head, eyes and pupil will be detected on the screen.
4. When all is properly aligned the first of 5 photos will be taken automatically.
5. Follow the arrows to tilt your phone to where they indicate: 1st upwards (Figure 2).

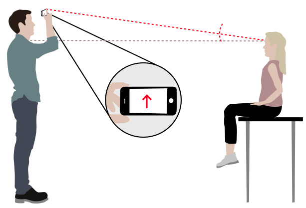

Figure 2: Drawing exemplifying the indications on the phone.

   (a) Repeat step 5 to down, left and right.
6. A menu will show up asking to send the data collected now or later.
   (a) Now: link your mobile phone to the internet (to your computer by wifi).
   (b) Later: When you want, enter in ”Records” - select the folder with the collection you want to send to analysis in a central server.

This protocol was included in the mobile application developed by us, which will be described in more detail in the section below.

4 DESIGN OF THE MOBILE APLLICATION

The information previously referred was used to design an application for eye signs screening. It was established that the user of the mobile application is going to be a non medical person who wants to collect data and receive a report on the eye health status, preferably from a child. When opening the application one disclaimer will appear, and the user may only can continue after agreeing with the conditions: the application does not replace a regularly ophthalmologist appointment. The reports act only as an alarm in case of some abnormality detection, for further evaluation from a clinician, nonetheless it does not substitute a regular visit to the ophtalmologist. Then the user will have three options: one for ”Collect”, other for ”Alert”, and one for ”Records”. But, as in Figure 3, all will be disabled because the user has to register a person in the application to start using it.

In a dropbox he can click on ”New”, and then will be forwarded to a new window. In this window (Figure 4) the user can write the name and the age of the child who he/she wants to screen and upload a photo for ID.

After he/she saves it, the application returns to the initial menu and the button ”Collect” will be now available, to initiate the collection with the respective person/child registered. After the first data collection

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Figure 3: Mockup of the start menu.

Figure 4: Mockup of the user registration.

Figure 5: Mockup illustrating the pop-up guide to the user.

made, the user may have access to the remaining buttons. For the option ”Collect” some instructions to this feature will pop-up to guide the user through data collection: to turn the lights down, to step away 4 steps from the person who he wants to trace (which will be in front of him/camera), and to use the zoom to capture the entire head (Figure 5). This way the user can apply the defined protocol and obtain useful data for processing/screening.

When the user finishes reading the instructions he/she can click the button to start collection. The camera will initiate, and the algorithm for face recognition will pop-up. When the detection of the eyes and pupil is reached, the phone shoots the first of 5 photos with flash. Afterwards, arrows will appear on the screen, indicating where to tilt the camera, and the process of detection of the face, eyes and pupil will repeat for right, left, up and down. When everything is in the right position, the photo is taken automatically, without requiring the user to press the ”shutter” button, like in 6.

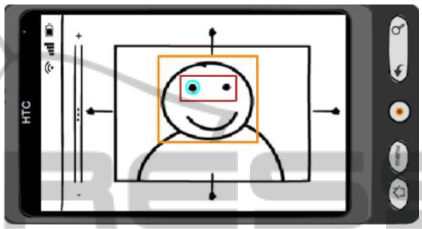

Figure 6: Mockup exemplifying one procedure of the tracing method.

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At the end, the user is prompted to choose between sending the collection now or later to the server. If he chooses now, this data will be sent to the server. Choosing to send it later, he returns to the start menu and may send it later in the ”Records” feature. In option ”Alert” of the front menu, the user will have indications to set an alarm of thirty days between collections. After this, the calendar of his phone will appear, where he can see other events that have been scheduled. Clicking on the desired day, and setting the time will set the alarm. Then, on the selected date, he will receive a notification to remind him of the collection. Nonetheless the application is available for data collection whenever the user decides to use it, regardless of the alarm set. Finally, when the user clicks on the button ”Records” (History), the application will redirect him to the gallery where he can see the different folders of previous data collection sessions. In each screening, one folder will be created to store all the information collected and corresponding reports. When the user opens the selected folder, he will have access to the photos recorded, getting 3 different options: ”Properties”, ”Delete” or ”Send”. In ”Properties” the non medical user can see the name, date and hour of the photo, and also the age of the person/child, in months, at the time of the collection. In ”Delete” he can erase it, and, in the ”Send” option he can send the chosen session to the server, if it has not been done before or if he wants to repeat it, receiving a new report.

4.1 Test Beds

The camera of the mobile phone needs to be controlled in such a way that face, eyes, and pupils are automatically detected, and then the necessary controls and instructions for the user are presented. Figure 7 is referent to the final aspect of the camera preview. Implementation of different sensors, like accelerometer, to detect motion when the user needs to follow the instructions, and light sensor to measure the illumination of the room, would be very useful in the application.

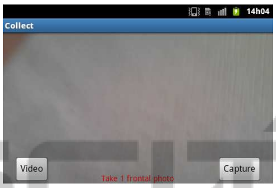

Figure 7: Camera's preview of the mobile application.

The developed mobile application (”EyePic”) was then tested following the required protocol and without the use of any external hardware. Figure 8 shows the result of the application with the proposed protocol and the white reflex necessary to evaluate the degree of strabismus (”Hirschberg test”). The dual flash of the mobile phone leads pupil closure, not allowing the presence of a red reflex, being this an issue to evaluate in further tests.

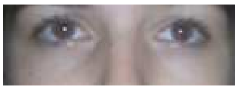

Figure 8: Binocular photograph taken with ”EyePic” mobile application.

This application was shown to some professionals of the area who express their opinion about the designed protocol, respective mobile application and early results. They agree that this kind of mobile application is very useful for various reasons, mainly because it is low-cost, but also because most parents are not informed or do not even have knowledge on the subject, the majority thinks they can not take a baby to an appointment, that he will not cooperate. So, because nowadays everybody adhere to mobile applications quite well, this new one, easy to access, allowing to perform a data collection at home and transmitting important information, becomes very usefull for an early ophthalmologist appointment. This is an important tool to battle with a delayed diagnosis, having, consequently, huge impact in the medical field. In fact, Brückner test plays an important role in detection of these eye pathologies, that must be detected as soon as possible.The main concern is the quality of the camera phone, which may not have the required conditions for a complete assessment of lunar reflections like in the Brückner test.

Relatively to the defined protocol, the lighting in the room should be low (as we noted when starting the data collection) in order to allow scotopic vision (vision produced by the eye in low light conditions) and frontal photos will be the ideal, since taken from another perspective may mislead.

A ”beta” version of this application will be tested at Hospital de Braga in a screening project named ”Pimpolho”, aiming to make an evaluation of the eye health of children aged 3 to 4 years, with special focus on amblyopia or some amblyogenic risk factors.

5 DISCUSSION AND CONCLUSIONS

In this paper, we propose the framework for eye pathology screening using a mobile application, with special emphasis in children and fast degrading eye pathologies. The most common diseases that benefit from early detection, and respective signs were described. This allowed for the design of a novel data collection protocol for a range of eye pathology screening, specially designed for non-medical users, and with only the technology available on a smartphone: camera and flash. In this application there is no need for external devices. Besides the features presented before, in the future we intend to make available a video recording what could add more value to the application, covering more eye pathologies, like nystagmus or other evaluation for strabismus (Training, 2014). But there are some important issues to be considered like the child's attention during the recording, and the accuracy required to implement it.

Given the importance of the eye diseases covered in this work, early detection is essential to a timely and effective treatment, making this mobile application quite advantageous, due to its practical and easy to use aspects for a regular monitoring, something extremely important for this diseases with high incidence during childhood.

In conclusion we can say that one of the strengths of this application is its accessibility: it can reage everyone, since low income countries where medical instruments are scarce (this can become an alternative); and mainly because allows a first screening, collecting usefull images to the detection of serious diseases. Its great advantage is the ability to store all collections made by date (records / history), and thus can be viewed by a medical expert. As parents with young

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children usually attend a pediatrician, and he only performs any non routine eye exam in case of alarm, it will be a great asset to have a visual history of the development of eye disease (if that manifest) for an accurate diagnosis. Also, a image repository can be achieved with this collection, not only for doctor evaluation, but for science research as well.

Besides all of that this is a very innovative mobile application, there are no currently similar applications, to our knowledge, including the same features an without the use of additional hardware to obtain the imagens for the analysis (Gallagher, 2013).

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