

A-eye

Implementation of AI in eye disease
detection

Master thesis

Integrated product design

Ward de Leve | September 2021

**TU Delft**

ksyos

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Executive summary

This project focusses on an AI service for the company Ksyos, that is able to detect different eye diseases like glaucoma, cataract and diabetic retinopathy. Ksyos is a Dutch digital healthcare institute, they try to deliver more accessible and affordable care to their patients by making use of new technologies. These new technologies make it possible to improve the capabilities of lower graded medical specialists. With these improve capabilities and by splitting the tasks of a diagnosis more efficiently among different grades of medical specialists the healthcare becomes more affordable.

Ksyos ophthalmology is one of the services they provide. This service creates a good collaboration environment for optometrists and ophthalmologists. Through this better collaboration diagnosis that previously need to be done by ophthalmologists in the hospital can now be done by optometrists in an optician store. The optometrist does the grading for the patient and the ophthalmologists evaluates this grading. This saves the ophthalmologists a lot of time which is necessary since the waiting lines for ophthalmology care are long.

There are developments in the field of AI in eye disease detection, test in laboratories show that AI is capable of detecting different eye diseases by just looking at a fundus picture. Ksyos is planning to create such an algorithm with their partner AI company, based on their own data set of fundus pictures. However, research show that a lot of promising AI systems eventually fail in healthcare sector. The reason for this besides accuracy is that the AI system not fit in the workflow of the different medical specialists, The added value of the AI system is not enough, the AI system is too difficult to use for the medical specialists and/or the AI system cannot communicate the results clear enough. This project focusses on how this promising AI system best can fit in the Ksyos ophthalmology service.

During the research all the aspects of the service are investigated, what the different diseases mean and how they can be diagnosed and treated, how this whole ophthalmology care system is organized, How the algorithm is created and what is possible with AI and the available data set, and what the etical aspects of letting an AI system take control over these screenings would mean.

what the etical aspects of letting an AI system take control over these screenings would mean, and looked at what is possible with the AI system and data to realize.

There were also interviews and observations done with multiple clinicians who play different roles in the Ksyos ophthalmology service like optometrists, ophthalmologists, and General practitioners, to get a good picture of their workflow and their reasons to participate in the current service. Based on all this research a new Ksyos AI service is developed.

In the new Ksyos AI service the optician gets a bigger role, not all the patients who get an eye screening need to be seen by an optometrist, around 90% of the people do not have any problems with their eyes. The optician is able to take the fundus picture and with this picture the AI system will be able to detect the different diseases. Only the patient that based on this first screening need to be seen by an optometrist will be send through. A simple overview of the service from the perspective of the patient is shown in figure 0.1.

Because the optician has not the knowledge and the capabilities to explain the results calm and clear to the patient, Ksyos will take over this task from him. Ksyos will send a letter with the results to the patient. The AI service will not be a screening service but a disease detection service, this means that the GP needs to count on the validity of the results of the system. To guaranty the quality the AI system will split the patients into three categories, green for people with clearly healthy eyes, red for people who have a severe case of the disease and orange for people who probably have an eye disease. The

orange and red patients will get a letter that tells them what the next steps will be, based on the disease and the color of the results this could either be going to an optometrist or to an ophthalmologist.



Figure 0.2. The UX interface for the optometrist of the A-eye service.

For the optometrist and the ophthalmologist, it is important that the AI system is able to explain what he has found. In most cases this is not necessary because these specialists are able to detect these diseases in seconds. But when the optometrist and the AI system do not agree on a diagnosis it is important that the AI system can communicate clearly what he found and where (Figure 0.2). Based on this information the specialist can decide if he agrees with the AI system or disagrees.

By implementing the AI system this way, the task of screening patients is better split among the available specialists and more people can be screened on asymptomatic eye diseases which makes the treatment of these diseases easier, better and cheaper.

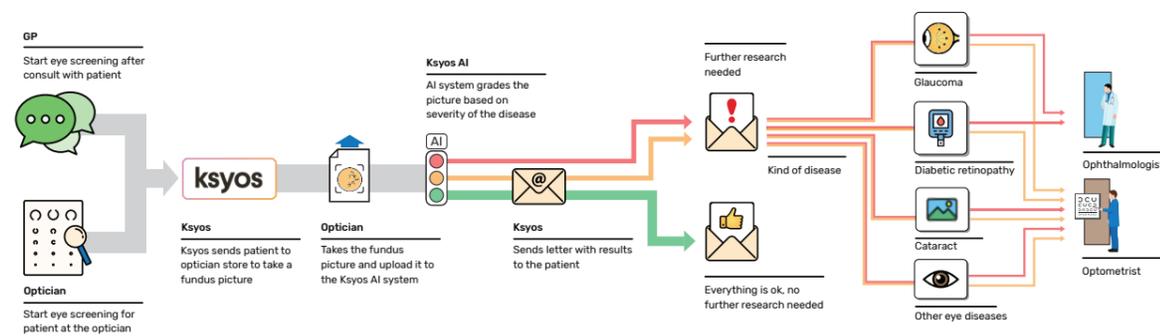


Figure 0.1 Simple overview of the designed service from a patients perspective

Introduction

Ksyos is a Dutch healthcare institute without a physical building, instead of a physical location they have a broad network of different medical specialists working for them at different locations across the country. Ksyos tries to deliver more accessible and affordable care to their patients by making use of new technologies. New diagnosis technologies make it possible for diagnostics formerly restricted to hospitals, to be done by paramedics close to the patient or even by the patients themselves. And by making good use of the communication capabilities of the internet diagnosis can efficiently be split among different grades of specialists.

One of the markets they are currently active in is the ophthalmology market. They provide eye screenings for diabetic people and more extensive research for people with other non acute eye problems. They split this task between optometrists who are often working in optician stores and ophthalmologists. The optometrists do the measurements and make a diagnosis and the ophthalmologist evaluates these results.

There are currently technical developments in this market, AI systems are developed that can look at pictures of the eye and determine the change a certain eye disease is developing. Ksyos does have a big data set of these eye photos and is collaborating with a company healthplus.ai to develop an AI system that is capable of detecting a couple of eye diseases. The goal of this research is to find out the best way to use the AI system and design a service around this that incorporates the needs of the different eye specialists involved.

Project Approach

The approach for this project follows the double diamond method. This method consists of four stages: the discover phase, the define phase, the develop phase and the deliver phase.

Research

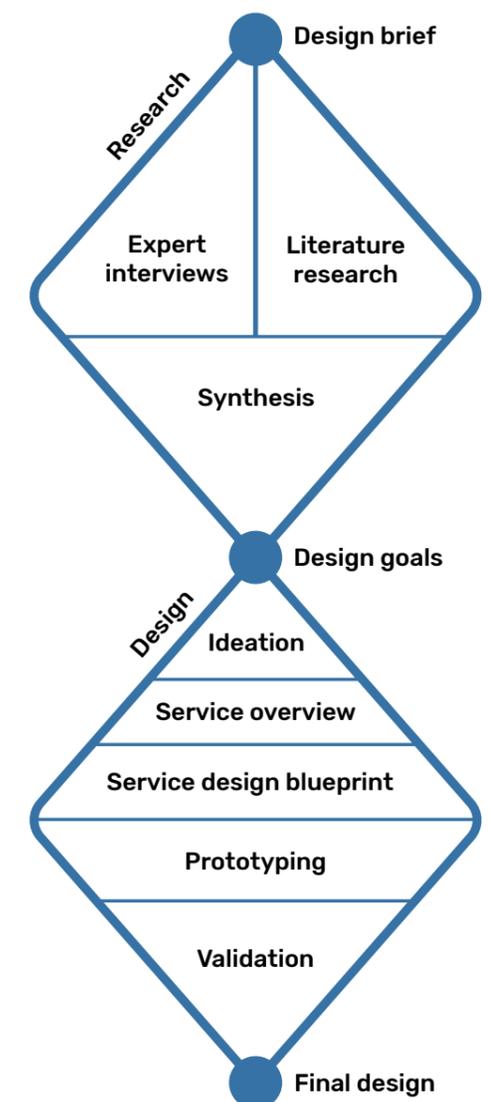
In the Discover phase knowledge is gathered through literature research about the diagnosis of eye diseases, treatment of eye diseases, the healthcare market, the current Ksyos ophthalmology service, possibilities, and limitations of AI systems and about the ethics of AI systems. Parallel to the literature research I did observations and interviews with experts. I talked with different opticians, optometrists, and a GP.

In the define phase the findings from the discover phase are translated through methods like SWOT, system maps and journey maps to more concrete insights. These insights are then used to create design goals that will be used as a starting point for the design phase.

Design

In the develop phase different rounds of how-to's are used to create a service that fits all the design goals. Based on these separate designs a design overview is made that shows the whole service. Through the creation of scenarios for the service several service blueprints are made to get a better overview of what is needed to deliver the service. Based on this the UX for the most important touchpoint is further developed.

In the deliver phase different methods are used to validate the concept, a concept walkthrough is used to validate the service and an experience prototype to test the workflow. Based on the results of these tests the final design is created.





Discover

- Eye diseases
- Ksyos company
- Healthcare market
- The algorithm
- Workflow
- AI ethics

1. Eye diseases

To understand which eye diseases can be discovered by an AI system we will look in this chapter to the different eye diseases, the diagnosing equipment, and the ways the diseases can be treated.

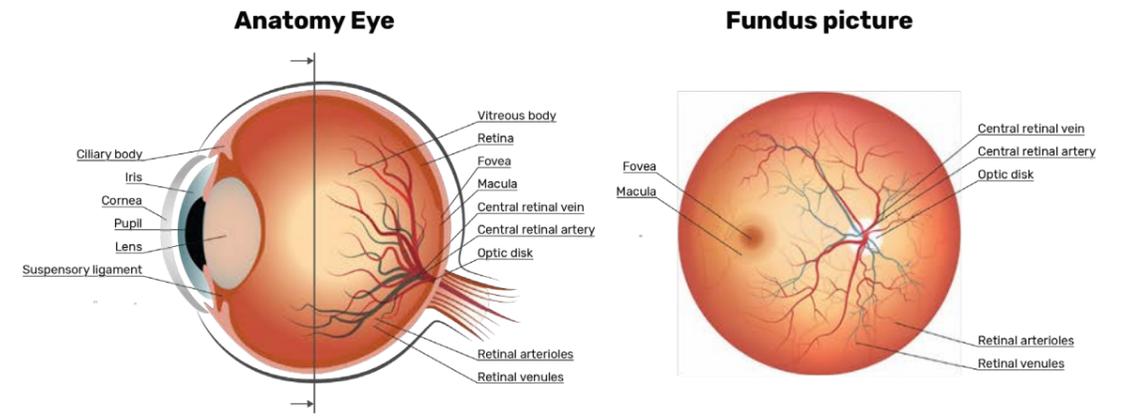


Figure 1.1. a) anatomy of the eye b) fundus picture of a healthy eye.

1.1 Fundus pictures

The AI system will use fundus pictures as input for detecting eye diseases. To understand what a fundus picture tells about the development of certain disease it is important to first know what you actually see on such a picture. A fundus picture basically shows the back side of the eye (the retina) as shown in figure 1.1. Within the retina you can see the Macula, this is the focal point of the eye where your sight is projected, the different arteries and veins and the optic disk. This is the point where all the veins and arteries exit the eye.

Based on fundus pictures different eye diseases can be diagnosed like Diabetic Retinopathy, Cataract and Glaucoma. These three diseases are all important causes of blindness in our society. By regular screening and with the right treatment vision loss can easily be prevented. Fundus pictures are a relative quick and easy way of pre diagnosing these diseases. Fundus cameras are available in a lot of optic stores in shopping centers across the nation, this makes the fundus AI scan an interesting tool for a preventive screen on eye diseases. To get a better picture of how the disease can be detected in the fundus pictures the three diseases will be discussed in-depth.



1.2 Diabetic retinopathy



Diabetic retinopathy is an eye disease that occurs by people with diabetes. The high blood sugar levels of these patients can damage the vessels in the retina of the eye, which can lead to vision loss. Diabetic retinopathy can be separated in four stages; mild nonproliferative diabetic retinopathy (NPDR), moderate NPDR, severe NPDR and Proliferative Diabetic Retinopathy (PDR). Below the four stages will be discussed separately.

often in groups. The microaneurysms usually appear and disappear over time. If the number of microaneurysms on the retina increases, it could be a sign of the progression of diabetic retinopathy.



Figure 1.3. Saccular outpouchings of the capillary wall

Mild NPDR

The first stage of diabetic retinopathy is called mild NPDR. In this stage the patient does not have any symptoms but the disease can develop quickly into a more severe stages of NPDR. In 5% of the cases Mild NPDR can develop within a year to PDR. The American academy of Ophthalmology advices to check patients with mild NPDR every 12 months (Ophthalmoscopy, 2002).

One problem with spotting microaneurysms is that they could look a lot like small bleedings (hemorrhage). An optometrist cannot see the difference between a small bleeding and a microaneurysms. The only sign that the red dot is a bleeding and not a microaneurysm is when the size of the dot exceeds the 100 μ m diameter (Triwijoyo et al., 2020).

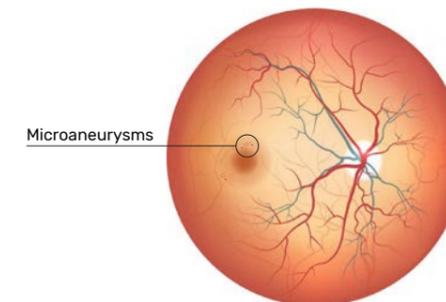


Figure 1.2, Mild NPDR with Microaneurysms

In the fundus picture, mild NPDR can be diagnosed by the presents of microaneurysms (figure 1.2). Microaneurysms are small saccular outpouchings of the capillary wall of a vein or artery (figure 1.3). On a fundus picture microaneurysms appear as deep red dots (Wiley & Ferris, 2013). The dots have a diameter between the 10 – 100 μ m and can be found

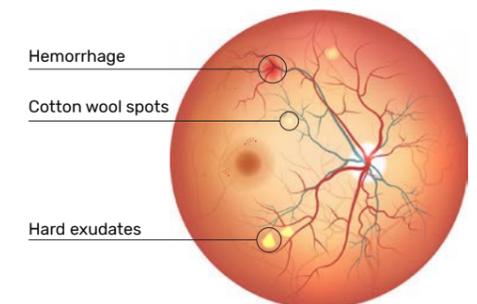


Figure 1.4, moderate NPDR with hemorrhage, cotton wool spots and hard exudates.

Moderate NPDR

The second stage of diabetic retinopathy is called moderate NPDR (Figure 1.4). In the fundus picture the amount of microaneurysms is increased and there is blood leakage on the retina called hemorrhage. The hemorrhage

is caused by the deposit of blood through microaneurysms or through rupture of blood vessel walls. Hemorrhage appears in different shapes from big round dots with sharp margins to flame shaped fading dots (Figure 1.5). The bleedings are not permanent and the blood on the retina can be reabsorbed, this will change the color of the hemorrhage to a gray-red color (Triwijoyo et al., 2020). Besides hemorrhage and microaneurysms a patient with the diagnoses moderate NPDR needs at least one of the following elements on the retina.



Figure 1.5, appearance of hemorrhage on fundus pictures.

Hard exudates

Hard exudates are caused by the deposit of small lipid and proteinic on the retina. This is the result of an abnormal vascular permeability which means that there are more holes in the blood vessels than necessary. The hard exudates appear as white/yellowish spots (figure 1.6) and are variable from size they can be found in isolation or in groups (Auccahuasi, 2020).

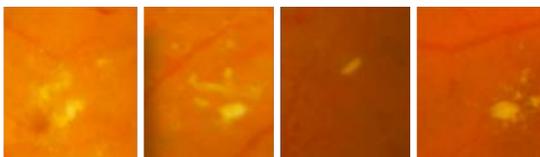


Figure 1.6, appearance of hard exudates on fundus pictures.

Cotton wool spots

Cotton wool spots look like small yellow/white spots in the shape of clouds with soft and hairy edges (Figure 1.7). They usually appear at the

corners of the main blood vessels or parallel to nerve fibers (Triwijoyo, 2020). Cotton wool spots are caused by the obstruction of retinal arteriole. This results in too little blood flow to certain parts of the retina called ischemia which causes a too low oxygen levels called hypoxia (Sharma, 2006). This causes swelling of the fibers and deposit of cytoplasmic material in the retina of the eye.



Figure 1.7, appearance of cotton wool spots on fundus pictures.

The deposit of this cytoplasmic material only happened on the back side of the eye the posterior segment. And usually not further than 1/3 away of the area of the optic disk. It causes rarely vision loss, only when the cotton wool spots appear in the macula. The spots usually disappear within 6-12 weeks (Patel, 2013).

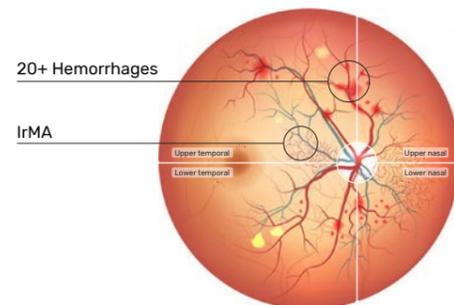


Figure 1.8, Severe NPDR with IrMa and more than 20 hemorrhages.

Severe NPDR

The third stage of diabetic retinopathy is called severe NPDR. For this diagnoses the fundus picture will be split in four quadrants as shown in figure 1.8. In this stage there are

more than 20 hemorrhages on the retina in all four quadrants. There will be venous beading in at least 2 quadrants. And IrMA development in at least 1 quadrant. This is called the 4:2:1 rule. IrMa stands for intraretinal microvascular abnormalities due to the obstruction of blood vessels in some areas hypoxia can cause the production of the hormone vascular endothelial growth factor. This will stimulate the production of new blood vessels (figure 1.9) by either sprout or intussuscept (Patil, 2020).

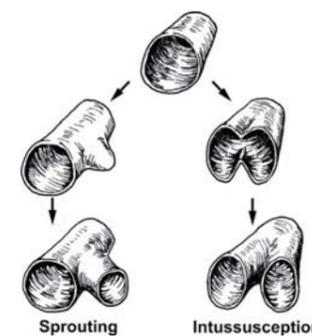


Figure 1.9, New blood vessels created by either sprouting or intussusception.

PDR

The fourth and last stage of diabetic retinopathy is called Proliferative Diabetic Retinopathy (PDR). In this stage immediate action is required. The patient will have progressive loss of vision or is already blind. PDR can cause either neovascularization or vitreous hemorrhage.

Neovascularization looks a lot like IrMA, there is also a shortage of oxygen which causes the production of the hormone VEGF. The difference with IrMA is that the new created vessels are not always patent, this can lead to leakage (figure 1.10). The new vessels start at the inner circle of the iris but can extend

radically even till the macula.

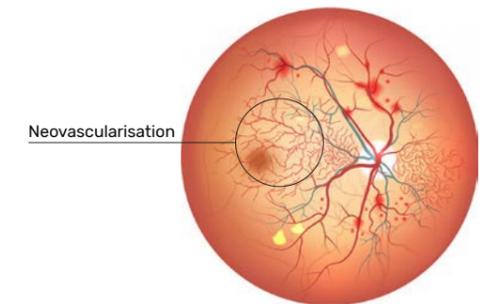


Figure 1.10, Neovascularization.

Another type of PDR is vitreous hemorrhage. In this case the new formed abnormal blood vessels bleed into the vitreous body, the clear gel in the middle of the eye. This can make it impossible for light to reach the retina and causes blindness (figure 1.11). Both of these types of PDR can be treated with surgery.

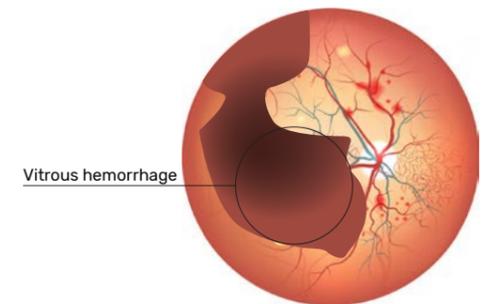
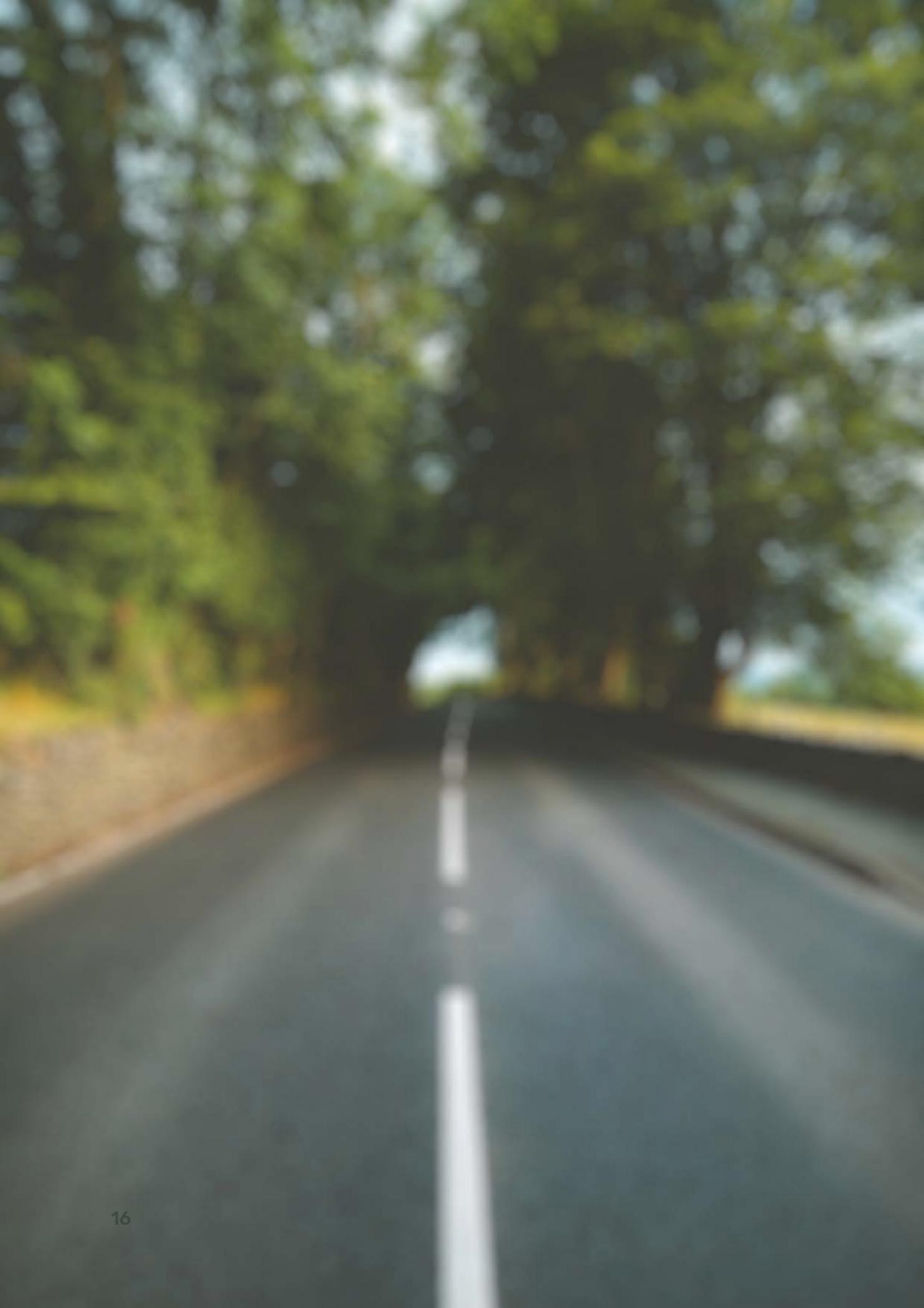


Figure 1.11, vitreous hemorrhage.

Macular retinopathy

When bleedings or leakages take place in the macula it is called macula retinopathy. Since the macula is the area of the retina that is responsible for the vision. The threat of causing vision loss is a lot higher when there is macular retinopathy.



1.3 Cataract

Cataract is another eye disease that can cause decrease of vision or blindness. Early signs of cataract could be blurry vision, faded colors or double vision. The decrease of vision is caused by the decrease of protein in the lens of the eye. The loss of protein creates a clouding texture in the lens which disrupts the light entering the eye. This causes the light to not project adequately on the retina. Cataract is the number one reason of visual disability and blindness worldwide.

Cataract in an early mild stage can be treated easily by for example stop smoking, healthier habits or wearing more often sunglasses. More severe version of cataract like moderate and severe cataract often need surgery to treat the disease.

The diagnosis of cataract happens usually with iris image projection, light-focus method, transillumination ophthalmoscopy or slit lamp examination. But it is also possible to detect this disease with fundus pictures. A fundus camera is as precise as the other techniques to detect cataract. The clinician could adjust the fundus camera to put the focal point on the lens. But even with keeping the focal point on the retina it is possible to detect cataract in the fundus picture (figure 1.12).

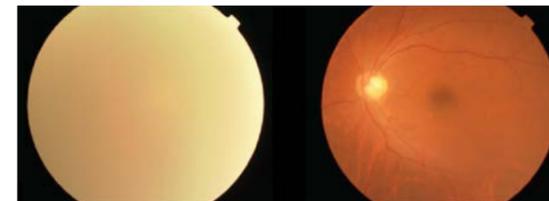


Figure 1.12, Fundus picture of an eye with cataract.

The grade of cataract can be described by the visibility of the retinal structure in the fundus pictures (Akil, 2020). In a healthy

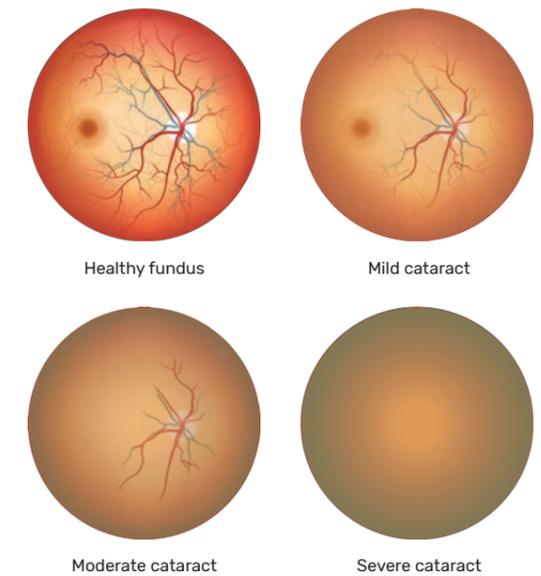
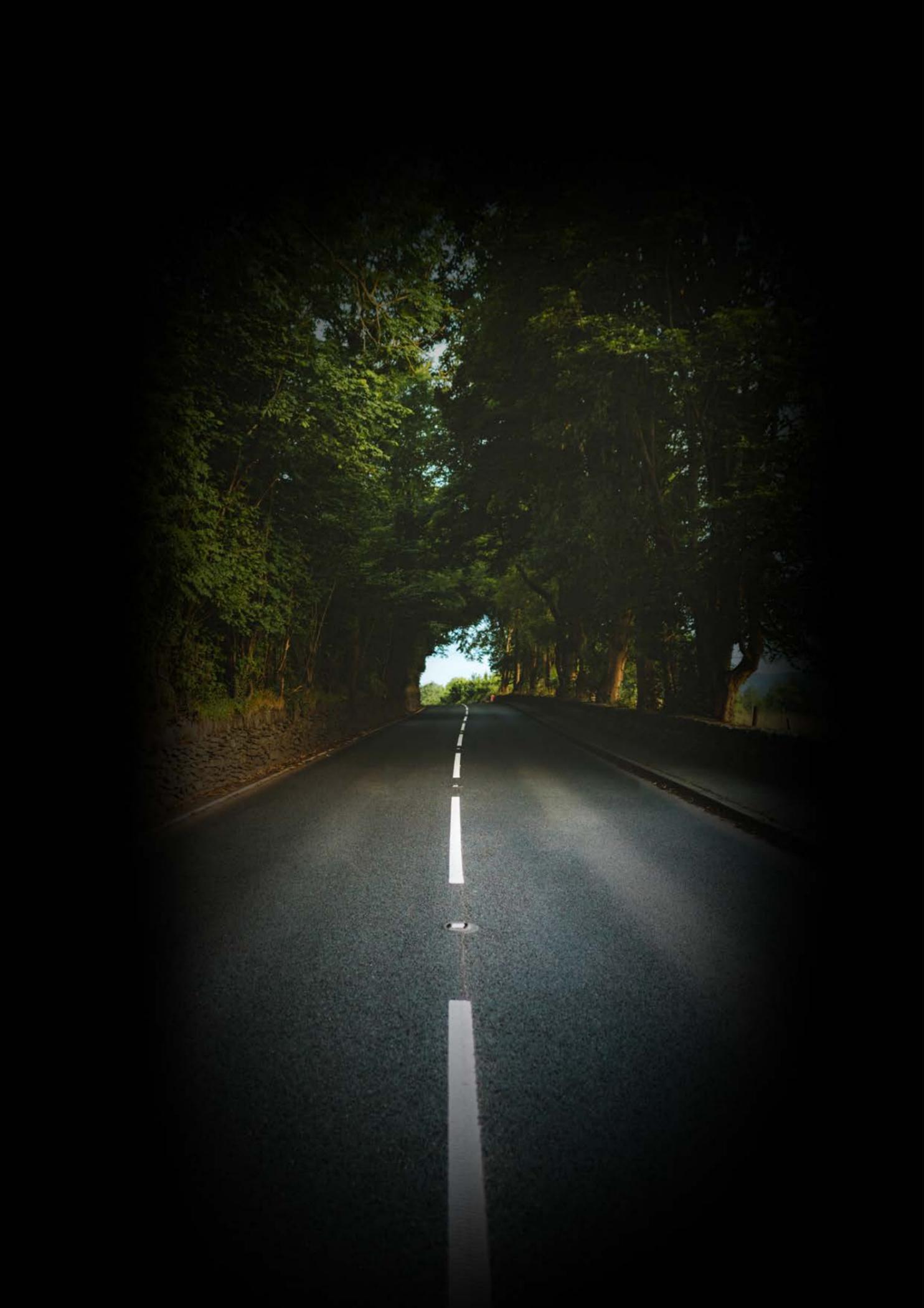


Figure 1.13, schematic drawings of how the different stages of cataract look on a fundus picture.

fundus pictures, all the retinal structure is visible, you can see all the thick and thin vessels and the optic disk. In fundus picture of patients with mild cataract you can still see all the vessels, but they are slightly less visible. Moderate cataract pictures show only the thick vessels. And in severe cataract picture no retinal structure is visible anymore (figure 1.13).

One problem that might occur is that there could be other conditions that causes a cloudy fundus picture, for example refractive error (Choi, 2013). Someone with myopia of 20/400 (this means this person sees at 20 feet what a normal person at 400 feet sees) could also have a blurry fundus picture. However this does not mean that this person has cataract.



1.4 Glaucoma



Glaucoma is a group of eye disease that causes damage to the optical nerve. The reason behind this damage is still unknown but heredity and an in balance of intraocular fluid are factors that have influence on the disease. The production of too much fluid in the eye or the blockage of fluid exiting the eye through the trabecular meshwork creates pressure in the front of the eye (Hagiwara, 2018). This pressure causes the vitreous body to push harder against the optic disc (figure 1.14), this will slowly damage the nerves in the optic disc.

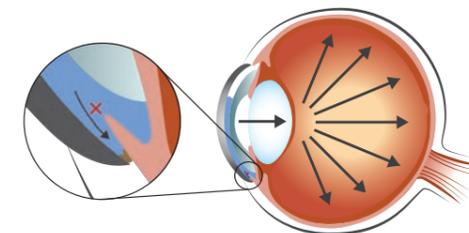


Figure 1.14, The blockage of fluid in the trabecular meshwork creates pressure that pushes the vitreous body against the optic disc.

Glaucoma has no symptoms before vision loss begins and is for that reason called the silent killer of sight. Treatment can prevent extra vision loss but cannot bring back any lost vision. To prevent the loss of vision the American Academy of Ophthalmology advices people between the 40-64 to screen their eyes on glaucoma every 2-4 years and people above 65 to scree every 1-2 years. But this does not happend.

Since glaucoma does not have any symptoms in the beginning stages, it is difficult to discover. Glaucoma is usually discovered by accident when people go to the optometrist or ophthalmologist for other eye problems. Measuring eye pressure is the simplest way to start looking for glaucoma, however a high eye pressure is more a risk factor than an indication for glaucoma.

Another less expansive way to diagnose glaucoma is by looking at fundus pictures of the eye. For glaucoma we focus on the optic disk part of the picture. By looking at the difference in size between the cup and the disc (cup to disc ratio), The distance between the cup and the disc at each of the four sides (Inferior Superior Nasal Temporal rule), and look at the alpha pigmentation zone (high pigmentation) and the beta pigmentation zone (irregular pigmentation) with Peripapillary Atrophy (see figure 1.15).

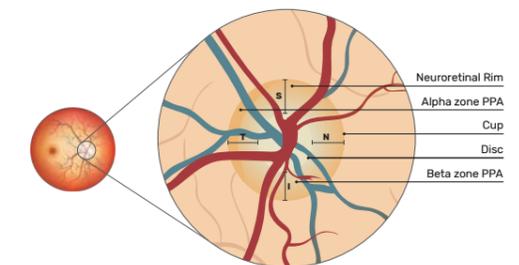


Figure 1.15, Close up of optic disk with elements that help determining the grade of glaucoma.

For this analysis it is important to segment the fundus picture correctly. A small mistake in this measurement can make a big different in the diagnose. That's why it is recommended also to look at the texture of the images to determine the size of the disk and the cup (Araújo, 2017). Some people indicate that these three methods are not enough and that the width of the rim should also take in consideration. That is why Disc Damage likelihood scale (DDLS) was introduced. The most important part for the AI system is that it is visible on a fundus picture if glaucoma is present or not. Besides the width Blood pressure, age and ethnicity also have influence on the development of glaucoma (Singh, 2014). When glaucoma is suspected based on a fundus photo the optometrist could use an OCT to get a better picture about the layers of the optic disc.



1.5 Diagnostic equipment



The fundus picture will be used as input for the AI system. In this paragraph we look at the types of cameras to take these pictures and the other equipment available at the optometrist.

Regular Fundus camera

Most optometrists use a regular fundus camera (figure 1.16). These cameras are expensive but produce the best fundus pictures. The camera takes a picture through the lens of the patient's eye. The patient is asked to look in a certain direction, the camera zooms in automatically and uses a big white flash to light up the retina and take the picture. The most modern versions of these cameras are able to adjust for myopia and can also take OCT's simultaneously. Because the pictures are taken through the pupil of the eye sometimes patients need mydriatic drops to increase the lens to take a good picture (when the pupil is smaller than 3.3 mm). All ophthalmologists I spoke indicated that in the near future these cameras will be able to take fundus pictures for all pupil sizes.

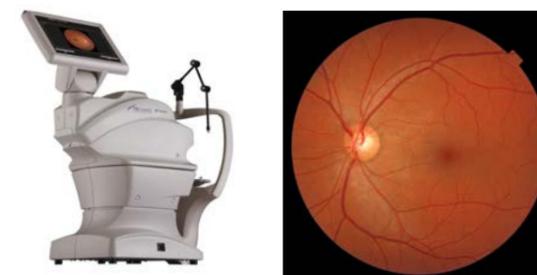


Figure 1.16. Regular fundus camera with an example of a picture it produces

Scanning laser ophthalmoscope

These cameras are actually no cameras but confocal scanners, they use a laser to capture the back of the retina. The advantage of this technique is that it works for everyone regardless of the size of the pupil. This means that patients never need mydriatic drops, and

that optician do not have to hire optometrists for fundus screenings. The disadvantage is that because a monochromatic laser is used instead of a white light flash, the pictures won't have natural colours. A black and white fundus picture is not ideal for detecting diabetic retinopathy (figure 1.17). For example, a black spot found on such a picture could be just a pigment spot (brown) or a hemorrhage (red).

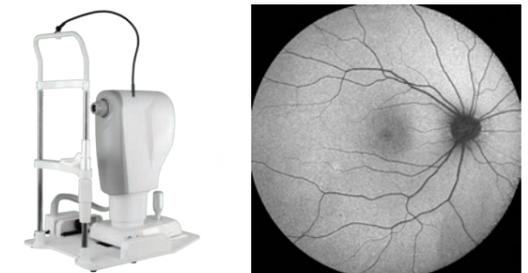


Figure 1.17. Black and white laser ophthalmoscope with an example of a picture it produces

By using more lasers operating at different wavelengths it is possible to create a pseudo color fundus picture. The computer uses the information of the different wave lengths to determine the colors. These colors however will not have a true color appearance, the computer could display the colors in a different way than the human eye perceives these colors. This makes these kind of pictures hard to read for optometrists and for AI systems that are not specifically trained for these pictures (Figure 1.18).



Figure 1.18. Color laser ophthalmoscope with an example of a picture it produces

Smartphone ophthalmoscope

The smartphone ophthalmoscope is the newest way of taking fundus picture. This tool makes use of the good camera already available in our smartphones. With a big lens the tool tries to mimic the regular fundus camera. However, the quality of the pictures is a lot worse (figure 1.19). The tool could be very useful for third world countries, but in comparison to a regular camera it is inferior.

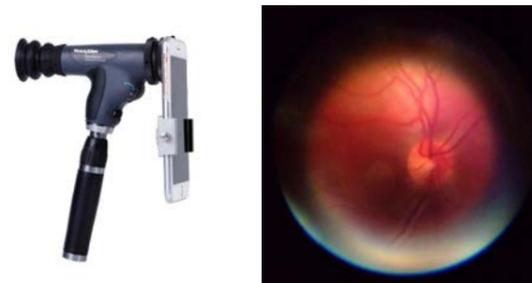


Figure 1.19. Smartphone fundus camera with an example of a picture it produces

Two pictures

During the screening the optometrist always takes two pictures from each eye, one from upfront and one nasal (figure 1.20). The two pictures together give a more complete overview of the retina. Because the two pictures are taken from different angles it gives spatial information. For example, by comparing the two picture you can see if a white spot is actually on the retina or just something on the lens of the camera.

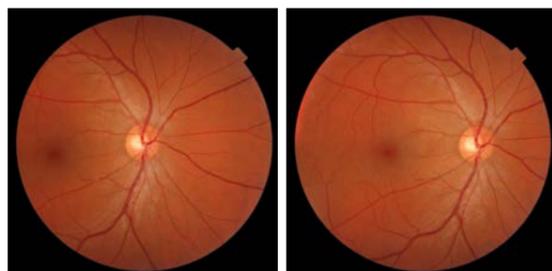


Figure 1.20. a) fundus picture upfront, b) fundus picture nasal

mydriatic drops

As discussed above the diameter of the pupil has a big influence on the quality of the fundus picture. When the pupils of a patient are too small mydriatic drops can be used to increase the pupil size. These droplets relax the circular muscles in the eye and contract the radial muscles (Figure 1.21).

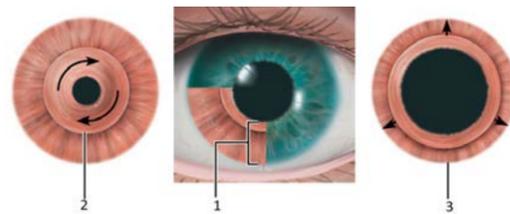


Figure 1.21. The muscles in the eye that are affected by the mydriatic drops.

Optometrist often use Tropicamide or Fenylefrine, these medicines are safe and delivered in pre dosed package. However, there is a risk of instant glaucoma because of a rapid increase of the eye pressure. Before putting these droplets in the eye of patients, the eye pressure is measured with a tonometer, this machine blows air into your eye and can roughly determine the eye pressure (figure 1.22).



Figure 1.22. A tonometer that measures the eye pressure.

Slit lamp

Next the slit lamp is used to determine if the anterior chamber in the trabecular meshwork

is closed (figure 1.23). When the eye pressure is alright and the chamber is open it is safe to put a droplet into the patient's eye.



Figure 1.23. a) Using the slit lamp, b) checking if the trabecular meshwork is open with the slit lamp.

OCT

An OCT scan show the intersection of the retina, this gives more information about the deeper layers of the retina (Figure 1.24). This type of scan is often used for more advanced eye screenings. But modern fundus cameras often have the ability to simultaneously take a fundus picture and an OCT. Some opticians take these OCT scans preventively for their patients, this way they can in the future better see if and where the quality of the eye is decreasing. However, most opticians do not take OCTs unless it is necessary. OCT scans take up a lot of computer storage and the law requires the optician to keep the OCT data at least five years.

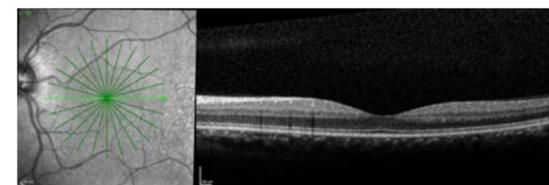


Figure 1.24. An OCT of the layers of the eye

Ophthalmologist equipment

The tools the ophthalmologist uses fall outside of the scope of this project since the AI tool is meant for diagnosis and not

for monitoring the disease. But to get a brief overview for retinopathy an ophthalmoscope is used to inspect a larger area of the retina to detect retinopathy or maculopathy. For glaucoma the ophthalmologist measures the visual field of the patient, the thickness of the cornea and the pressure in the eye during the day. For cataract it is important to know the visus of the patient to decide if it is necessary to operate.



1.6 Treatment

Since the AI system is meant for referring patients to an ophthalmologist it is important to understand at what stage of the disease this should happen. In this paragraph we discuss briefly what the next steps are after diagnosing the different diseases.

Diabetic retinopathy

When the first stage of diabetic retinopathy is discovered, treatment is not started immediately. The ophthalmologist will wait until the vision of the patient starts decreasing. The leakages that appear in an early stage could easily disappear naturally. It is important in this stage to screen the patient more frequently. The ophthalmologist keeps track of the development of the retinopathy in the retina and the macula. And he also keeps track of the fluctuations of the sugar level of the patient and the visual field. Based on these data he can start the treatment at the right time. The lost vision will almost never return that's why it is important to act quickly (figure 1.25).

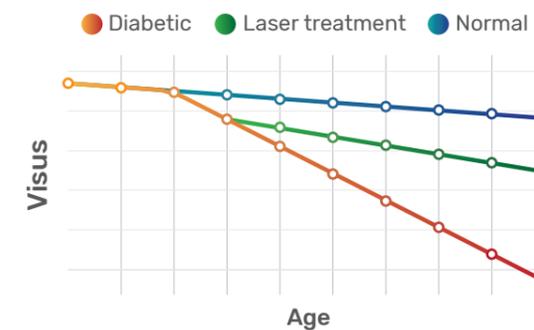


Figure 1.25, The timing of laser treatment need to start when the visus will go down to prevent vision loss.

Laser treatment

Diabetic retinopathy can be treated with laser treatment often the Argon laser is used. This small laser could help to slowdown or stop the vision of getting worse. Often multiple treatments are necessary over a longer time



period based on the retinopathy stage the treatment started.

Three types of laser treatments are available for diabetic retinopathy based on the stage of the disease. The laser treatments are focal laser treatment, grid laser treatment and panretinal laser treatment (oogarts.nl, n.d.).

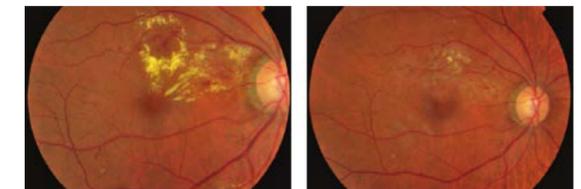


Figure 1.26, Focal laser treatment

Focal laser treatment has the smallest impact on the retina. It is used in an early stage of the diseases somewhere between moderate NPDR and severe NPDR. This treatment is only used when blood, fluid or lipid leakages appear in the macula. The small laser will precisely hit these spots and stop the leakage. This will prevent further vision loss (figure 1.26).

Grid laser treatment cannot be used in the macula. It is meant to target bigger areas of leakages. Instead of using a precise focal point a grid laser uses multiple target points in an area, which creates a grid of laser spots.

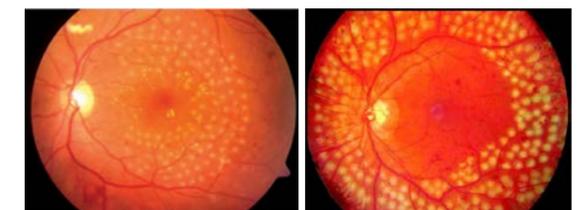


Figure 1.27, a) Grid laser treatment, b) Panretinal Photocoagulation treatment

Panretinal Photocoagulation treatment has the biggest impact on the retina. This treatment is used in the (Pre-)PDR stage. This laser treatment almost targets the whole retina. The goal to the treatment is to prevent the creation of new blood vessels

and to reduce the amount of not wanted blood vessels. The laser will reduce the amount of VEGF in the blood vessels. The VEGF hormone which is responsible for the creation of new blood vessels.

Cataract

Cataract is a disease that eventually everyone will get when they get older. It is not necessary to direct these people immediately to the ophthalmologist. The time does not have influence on the treatment or the result of the treatment. There is only one type of treatment and that is surgery. During cataract surgery the patient lens will be replaced by a plastic one. The patient needs to decide themselves if and when they want this type of surgery. The moment the patient decides he wants the treatment he should be referred to an ophthalmologist.

Glaucoma

As discussed before it is still unknown what causes glaucoma. What we do know is what factors influence the change of developing glaucoma. These risk factors are family history, dark skin color, high eye pressure levels and nearsightedness. Since high eye pressure is the only factor that can be changed, the treatment of glaucoma is focused on lowering the eye pressure.

When glaucoma is diagnosed the ophthalmologist often wants to see the patient quickly. Because vision that is lost won't come back. By lowering the eye pressure in an early-stage vision loss can be prevented. When the disease is diagnosed by an older patient (for example 85 years old) there is less hurry. The change that this person will develop severe vision loss during his life is small.

The treatment of glaucoma is based on a target eye pressure, often 30% lower than the current eye pressure of the patient. The first type of treatment are eye droplets, there are different eye droplets that trigger other mechanisms. There are droplets that reduce the production of fluid in the eye and there are droplets that make it easier for fluid to exit the eye. These droplets can either be used separately or together.

When it is not possible to control the eye pressure by eye droplets the second step is laser surgery. In this stage a part of the trabecular meshwork will be burned away (Figure 1.28). This makes it possible for fluid to exit the eye again. If the procedure works it will last from 3-5 years and it can be repeated.

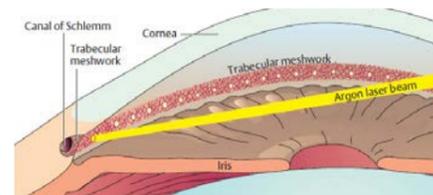


Figure 1.28, argon laser beam on trabecular meshwork

When medications do not work and the laser won't open the trabecular meshwork, the third option is knife surgery. This surgery is used to create a new place for fluid to exit the eye by cutting a small hole below the eyelid of the patient (figure 1.29). The fluid that exits through this hole will not become tears but will be absorbed by the vessels around the eye.

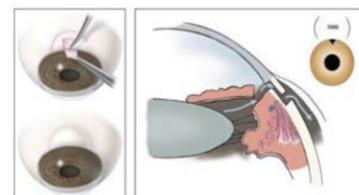


Figure 1.29, knife surgery to create new hole for fluid to exit the eye

Conclusion

There is an opportunity to diagnose these three different eye diseases with a single measurement tool the fundus camera. An AI system could make this diagnoses a lot more accessible because it enables less schooled people to run these diagnoses. For the algorithm it is important to determine the next steps for the patient based on the type of disease, since not all eye diseases require the same next steps. Another important point is that there are different types of fundus pictures, normal and radar pictures. For diabetic retinopathy the difference is not that big of a problem but for detecting glaucoma it could be.

Key insights

- For the algorithm to function well in the real-life context it needs to treat the detection of the different eye diseases differently. The next step after detecting glaucoma is different than cataract.
- Not all cameras are the same and produce the same kind of pictures. Pictures taken with a laser camera are easier to be taken by unschooled people but more difficult to read for ophthalmologists. The kind of picture could have influence on how well the algorithm functions.
- For most fundus cameras right now 50-20% still need mydriatic droplets. These droplets can be given by optometrists and not by opticians this limits for now the possibilities to let less schooled people take the fundus pictures in the new service. But according to ophthalmologists these percentages will drop quickly in the near future.

2. Ksyos company

In this chapter the company Ksyos is further analyzed to get a better picture of the company, the current ophthalmology service and how the AI system will fit in their portfolio.



2.1 Digital healthcare institute



Ksyos is a Dutch healthcare institute without a physical building. They provide care by making good use of the internet. Paramedics and medical specialists all work at different locations and are connected to each other and to the patients through the Ksyos platform. Usually, working for Ksyos is a part-time job they do next to other obligations (like selling glasses).

The goal of Ksyos is to deliver more accessible secondary care closer to people's homes. To achieve this Ksyos uses technologies that enable diagnostics formerly restricted to hospitals, to be done by paramedics

close to the patient or even by the patients themselves. Next to using more accessible technology and shifting tasks, Ksyos uses its network of medical specialists to provide diagnosis and treatment. This way different steps in the diagnoses of a disease can efficiently be split among different grades of specialists.

“Making healthcare accessible and affordable for everyone, with a minimum travel and waiting time”



Around 4.500 medical specialists are working for Ksyos, and 7.500 general practitioners in the Netherlands are referring to the secondary care services of Ksyos. At the headquarter in Amstelveen 120 employees work on improving the services. Ksyos currently focuses on 8 health categories: Cardiology, GGZ, Dermatology, eyecare, sleep care, pulmonology, digital consults, and laboratory research. Each of these categories makes use of the benefits of Ksyos in their own way.

For example, Ksyos dermatology provides GP's with an innovative simple dermatoscope attachment for their smartphone (Figure 2.1). This can be used to take detailed pictures of skin problems such as moles. This makes the first step of the diagnosis easy for someone with less expertise in dermatology. Through the Ksyos platform, this picture can be sent to a Ksyos dermatologist, who provides a diagnosis and treatment advice.



Figure 2.1, Ksyos dermatoscope attachment for smartphone

When the GP refers a patient with cardiology problems to Ksyos, Ksyos cardiology will send a holter to the patient's home including the instructions (Figure 2.2). The patient can attach the electrodes himself. After wearing the holter a few days, the patient sends back the device to Ksyos. The data the holter collected are uploaded to the Ksyos platform and a Ksyos technician makes a preliminary report. Finally, this report is reviewed by a cardiologist who reports his findings to the GP.

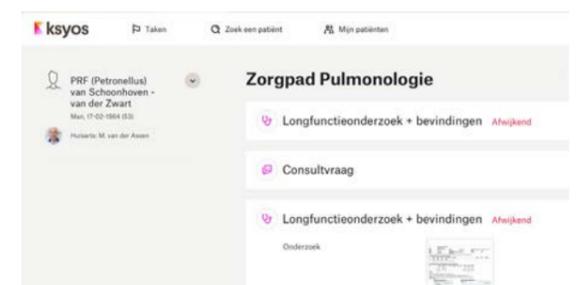


Figure 2.2, a) Holter for patient with instructions, b) Ksyos platform for cardiology.



2.2 Ksyos Ophthalmology



Ksyos ophthalmology is their service that focuses on eye care. The AI system will become part of this service. Ksyos ophthalmology currently consists of three different services that all focus on non-acute eye care. The services use a smart division of tasks between optometrists and ophthalmologists. The services aim to make quality eye care better accessible closer to people's homes.

Retinopathy screening

The retinopathy screening is a service for diabetic patients. These patients have a change of developing diabetic retinopathy, an eye disease that can result in blindness. The goal of this preventive screening program is to detect retinopathy in an early stage, to prevent unnecessary vision loss.

General Ophthalmology Examination

Other non-acute eye diseases like cataract and glaucoma can also be diagnosed by an optometrist. The GP can refer patients with the Ksyos general ophthalmology examination serves to an optometrist nearby. The diagnoses of the optometrist will always be checked by an ophthalmologist. The optometrist can also start a general ophthalmology examination himself when he finds something suspicious during a retinopathy screening or during a regular screening of a customer in his optician store.

Orthoptic Examination

This examination focuses more on the muscles in the eye for example diagnosing a lazy eye. This falls outside the scope of the AI system.

The to be developed algorithm will focus mainly on the retinopathy screening, but could also potentially be used to detect glaucoma and cataract. Since the input for the algorithm will be a fundus photo. We will now look at the current journey of taking a fundus picture during a regular retinopathy screening.

Care path

The current system consists of two main players the optometrist and the ophthalmologist. The optometrist takes and grades the fundus pictures. The ophthalmologist does quality checks to guarantee a good service. In this paragraph, we walk through the different steps of the service.

1. Appointment

The development of retinopathy needs to be checked every 1-3 years based on the results of previous screenings. The GP is responsible for the patient and will refer the patient to Ksyos retinopathy screening. The patient can pick one of the participating optometrists or medical diagnostic centers from a provided list. He has to make an appointment himself.

2. Taking fundus picture

The fundus photo can be taken by a laboratory technician (working at a medical diagnostic centre) or by an optometrist. The laboratory technician will only take the picture pictures without grading. He will also do some additional measurements

like the eye pressure and the visus. All this information will be entered in the first part of the fundus screening form (see paragraph 2.3) and uploaded to the Ksyos platform.

3. Grading fundus picture

The optometrist will grade the pictures he took himself or uploaded pictures from the laboratory technicians. The grading is based on a clear retinopathy scale. After the grading he provides an advice for the GP. The completed form will be sent to the GP.

4. Evaluate gradings

The ophthalmologist looks at small percentage of the retinopathy gradings from the optometrist. This percentage is based on negotiations with the care groups and usually around 5%-10%. The feedback of the ophthalmologist will be send back to the optometrist, this way the optometrist also knows what he could do better next time.

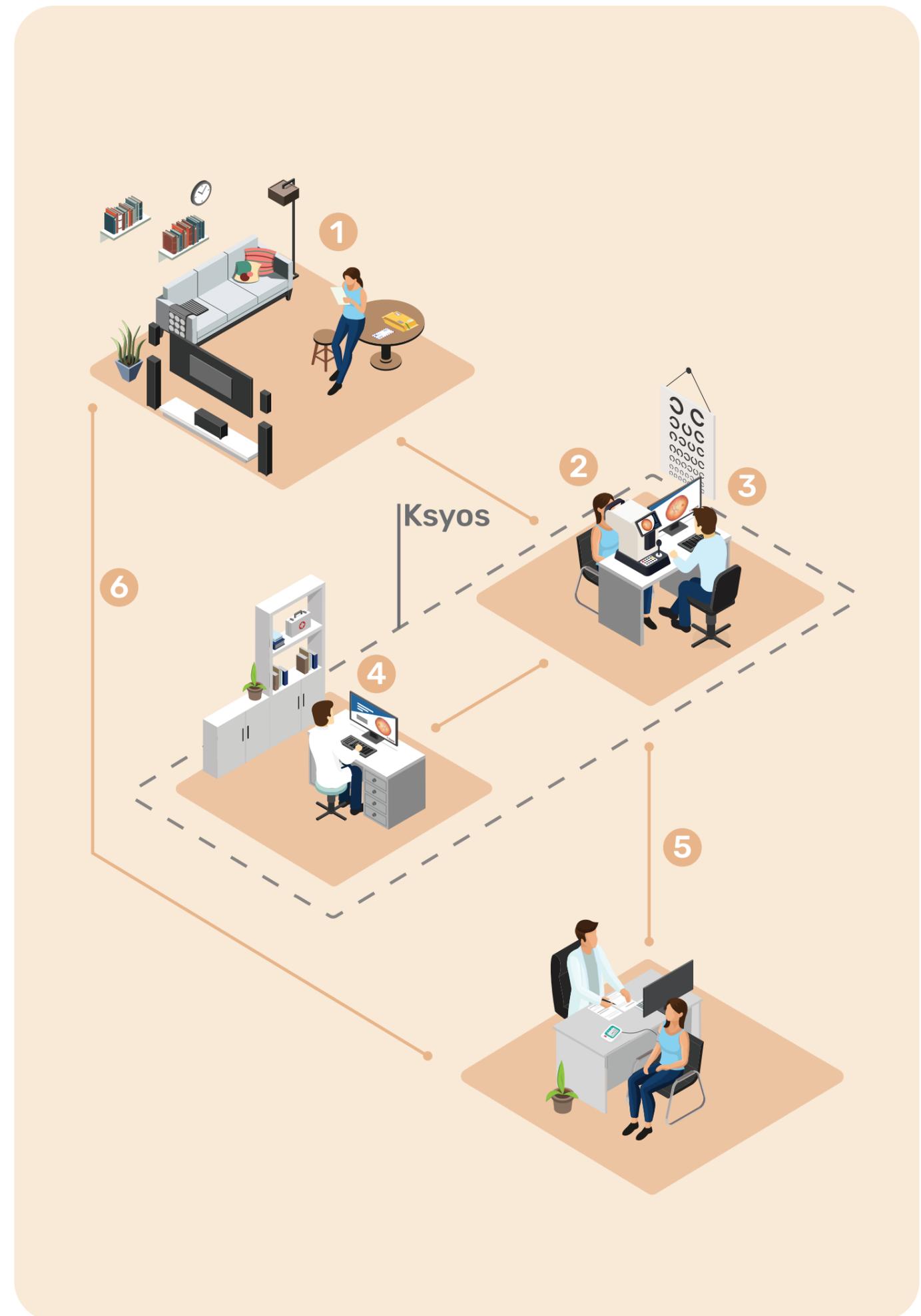
For a general ophthalmology examination, the process is different in this case 100% of the gradings of the optometrists are evaluated by an ophthalmologist.

5. General practitioner

The general practitioner receives the results of the screening of the patient. When they do not trust the diagnosis Ksyos provides a second opinion from a Ksyos ophthalmologist. The general practitioner is the one who decides what will be the next step in the process.

6. Other diabetic care

In addition to the fundus screenings diabetic patients have a lot more checkups. Most of these checkups are done by the GP or assistant. Every 4-5 months a diabetic patient goes to the GP for a regular diabetic checkup. During these checkups things like blood pressure and glucose values will be measured.



2.3 Fundus screening form



Looking closer to the Ksyos ophthalmology service you see that the Ksyos platform is the most important part of the service. This platform is used by the optometrists, the ophthalmologists and the GPs to communicate with each other. The most important element for the fundus screenings is the digital fundus screening form. This form consists of two part, the first part is all about entering the measurements and the second part is about diagnosing a disease.

Measurements

The measurement section of the form can be filled in by everyone who is capable of taking fundus pictures (figure 2.3). This could be a laboratory technician or an optometrist working for Ksyos.

Four pictures need to be uploaded in the form, two of each eye. one picture from up front (central) and one picture from a slide angle (nasal). These two pictures together give a broader view of the retina which makes it easier to spot problems. The fundus pictures of the right eye need to be uploaded at OD (oculus dexter), and the pictures of the left eye need to be uploaded at OS (oculus sinister).

In addition to the fundus pictures often the optometrist will also measure the visus of the patient. The visus is measured with a Snellen chart, this is a chart with different characters or circles with holes. The patient needs to cover one of their eyes and explain what characters they see on the chart. Based on

these results the optometrist can determine how clear the patients vision is.

The last measurement that is measured is the intraocular pressure. This is a important risk indicator for glaucoma. The pressure can be measured with a Goldmann applanation tonometry. This is a machine that available in most optician stores.

Grading

Based on the measurements from the first part of the form in the second part the optometrist will indicate the grade of the disease in each eye based on the criteria

discussed in chapter 1.2. He will also indicate if the disease is developing in the macula or somewhere else in the retina. And he will. Write an advice for the general practitioner. Then he will hand the form in on the ksyos platform.

The ophthalmologist gets 5%-10% of all the filled in forms and will evaluate if the diagnoses the optometrist suggests are the right ones. When the ophthalmologist thinks the optometrist made a mistake, he could use the Ksyos platform to let the optometrist know.

Upload fundus pictures

visual acuity score (visus)

Intraocular pressure

Eye droplets

Figure 2.3, The Ksyos ophthalmology form split into a measurements part and a grad part.

Grade of retinopathy

Presence in the macula

Other symptoms

Advice for the GP

2.4 Competitors



Just like Ksyos other companies are also trying to implement AI into retinal eye scanning. There are no big companies yet in this market most of them are sort of startups. The two biggest players right now are Digital diagnostics and Airdoc. Digital diagnostics focuses mostly on the US market and Airdoc on the Chinese market.



Digital diagnostics is right now the biggest player in the field of AI eye diagnostics. They were the first company who got an FDA approval in 2018 for their AI eye screening tool IDx-DR. This device is able to detect the presents of Diabetic retinopathy and macular edema. It is a quite accurate algorithm that can not only detect the stage of retinopathy but also the kind and number of feathers detected like Microaneurysms and cotton wool spots.

Airdoc

Airdoc is another recently founded company that focuses on AI disease diagnostics. The Chinese company is backed by Sogu the second largest search engine of China. They currently have no products on the market, but they have developed an AI retinal health risk assessment tool. They are currently trying to get an FDA approval, but the CEO claims that the FDA rules should change

because right now it is almost impossible to get an FDA approval.

DEEPDEE

There are also a lot of smaller companies that try to enter this market like the Dutch company DeepDee. They are more focused on the European market but don't have any product on the market yet. People who are interested could request a demo of their retinal scanning algorithm. In comparison to Ksyos they do not have an existing network of general practitioners and specialists. This makes it more difficult for such a tech company to enter this market.

Overall, the market of AI retinopathy diagnoses is still developing and the different companies are still trying to find out what they want to do with their algorithms. This means there is still room for competitors to figure out the best way to implement the algorithm.

2.5 SWOT analysis

Strengths

- ◇ Experience in the market of eye diagnosis
- ◇ Existing Network of medical specialists
- ◇ A well-known name in the market
- ◇ Capabilities to provide a whole service
- ◇ Big data set of Dutch fundus pictures
- ◇ Experience with providing services
- ◇ Good AI collaboration partner

Weaknesses

- ◇ Not an AI/tech company
- ◇ Operate only in the small Dutch market
- ◇ No functional AI system developed
- ◇ Current service described as expensive
- ◇ Dependent on the optician market

Opportunities

- ◇ Providing an extended AI service
- ◇ Combine partners and AI to deliver a better service
- ◇ Developing an AI system optimized for the Dutch market

Threats

- ◇ Other parties develop a more accurate AI system
- ◇ Bigger companies could take over the Dutch market
- ◇ Cameras could integrate the AI software

A SWOT analysis is a tool that helps a company to decide the direction it should be heading to, by analyzing internal and external factors.

Strengths

The biggest strength of Ksyos is the creative use of different specialists to provide a qualitative good service at a low price. They have the knowledge and the capabilities to provide not just a diagnosing tool but a whole service. They also have more than 10 years experience in the eye disease diagnosing market and have a big data set of Dutch fundus pictures.

Weaknesses

A weakness of the current ophthalmology service is that it depends fully on the optician market. When there will be a shift in this market the existence of the whole service comes in danger. Ksyos is also not a tech company and these are the first steps in the AI market. The competitors are mostly AI companies with more than 10 years experience in developing retinopathy AI systems. But Ksyos does have a partner company who has experience in developing AI systems for healthcare.

Opportunities

A big opportunity for Ksyos is providing the service around the AI system. Most of the competitors in the AI retinopathy market are focused on developing the AI system. But the AI system alone will not be enough to provide the whole screening process. The strength of Ksyos is to provide a service that combines the expertise of the different specialists with new technologies and combine that to deliver an efficient and affordable service. A second opportunity is the development of an AI system focused on the Dutch market. Fundus pictures diverse a lot based on pigmentation rate. Ksyos has a data set of more than a million fundus pictures, these pictures are a good representation of the Dutch market.

Threats

Other parties could develop a more accurate AI system and even integrate this into camera systems. This will mean that the AI system developed by Ksyos will not be necessary anymore. However, the service around the AI system will most likely still be necessary when other parties take over the AI part of the system.

2.6 Stakeholders



Figure 2.4. The Stakeholders involved in this AI project

In this paragraph we look at the different stakeholders that will be part of the new ophthalmology service that will be build around the AI system. The stakeholders that are part of the service are the patient, the optometrist, the ophthalmologist, the optician, the general practitioner, the Zorggroep and the companies Ksyos and Healthplus.ai (figure 2.4).

Patient: The patient / customer will be the user of the new AI ophthalmology service. He needs to trust the validity of the service. The retinopathy screening is not mandatory, this means that the patient decides if he thinks it is worth it to do the screening.

Optician: The optician will have to join the optometrist in taking fundus pictures. He needs to see the value of the new service for his business.

Ksyos: Ksyos is the company that currently provides the fundus screening service. They want to improve their service to deal with lower coverage of health ensures.

Healthplus.ai: Healthplus is a company specialized in developing AI systems for healthcare, they partner up with Ksyos to develop this new service. They want to extend their portfolio to strengthen their position and develop more knowledge in the AI for healthcare market.

Optometrist: The optometrist is the one who grades the fundus pictures in the current system. It is not a profitable service for them. They use it to provide better service to their customers. They like it if the new service could relieve them from some work but the quality of the screenings should not decrease.

Ophthalmologist: The ophthalmologist wants a system that is accurate enough and clear in communication, they do not want a huge stream of patients that do not need to go to the ophthalmologist.

General practitioner: The GP is the one who decides to work with Ksyos and brings new patients into the Ksyos platform. The GP needs to trust the AI service and get clear understandable information back from the system. They do not want unclear results or patients who got in panic for no reason.

Zorggroep: The zorggroep is the one who brings money into the system. It is important that they think the system is accurate enough to trust. Otherwise, they won't use it.

Power interest grid

A power interest grid can help to give an overview of the different stakeholders involved in current projects of a company. It also shows the interest and influence of each different stakeholder. The most important stakeholders for a company are the ones with great influence and great interest.

The most important stakeholders are the two companies who are working together to develop this solution, Ksyos and Healthplus.ai. And the three groups of specialists who are currently working with the Ksyos ophthalmology service the the optometrist, the ophthalmologist, and the general practitioner. The optician does also have influence and interest but not as much as the current partners (see figure 2.5).

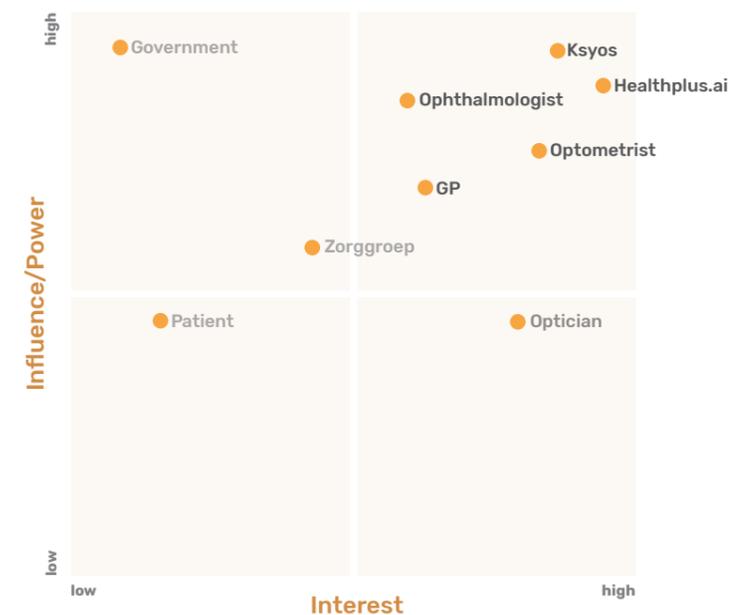


Figure 2.5. Power interest grid of the different stakeholders

2.7 Values stakeholders

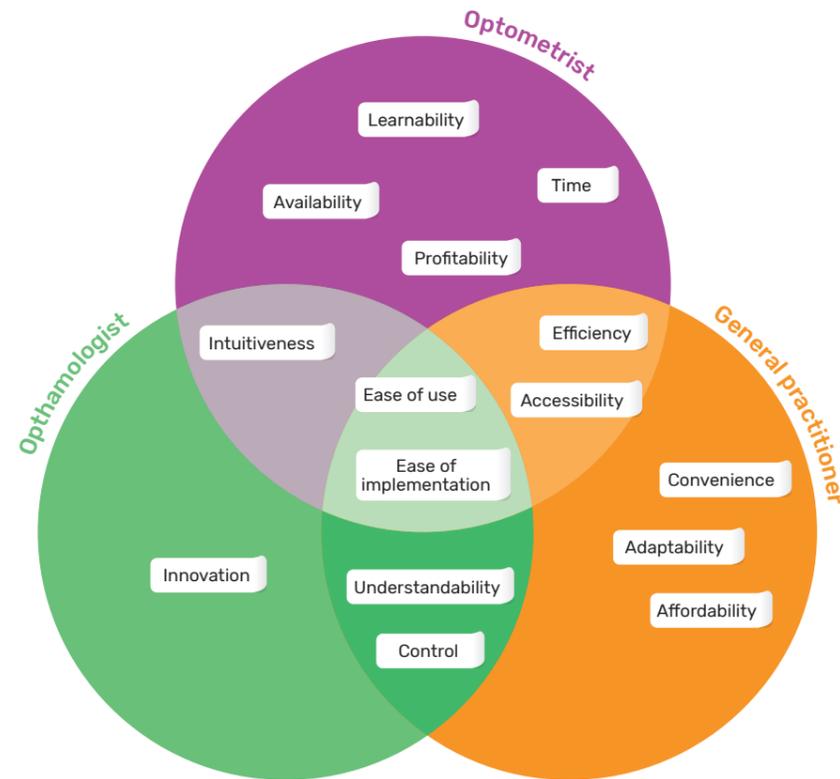


Figure 2.6. Values of the three most important stakeholders

Based on interviews with the different stakeholders some needs are determined for the to be developed service (figure 2.6). The three most important stakeholders have different needs, but they all want the service to be easy to understand and implement. The specific needs of each stakeholder are described below.

The general practitioner

For the GP the system needs to be affordable otherwise they will search for different ways to provide in their need for retinopathy screenings. The service needs to be efficient and easily adaptable to different circumstances, like different setups of screening programs.

Optometrist

The optometrist is an entrepreneur and for him, the profitability and time it takes to perform the scan are important factors. Besides that, he likes the opportunity of learning new things through the current Ksyos service.

Ophthalmologist

For the ophthalmologist the control is important he does not want too much more patients who are referred to them unnecessarily. The system itself should be intuitive, and the results should be sort of understandable.

Conclusion

Ksyos has good opportunities to enter the market of AI retinopathy screenings. They already have a position in the retinopathy screening market and experience in delivering a whole service. For the AI service it will be important to keep using the existing network of medical specialists. To keep these specialists happy, it is important to develop the AI service to fit their needs. The service should therefore be easy to use and implement. For the optometrist the service should be direct or indirect profitable. And for the ophthalmologists and the general practitioners the service should be adaptable and controllable to fit their needs.

Key insights

- There is an opportunity for Ksyos to distinguish itself from its competitors, by focusing on the service as a whole instead of just the algorithm.
- The strength Ksyos should use in the to be developed service is their existing network of medical specialists.
- For the service to work for general practitioners and ophthalmologists the service needs some form of control and/or adaptability so it fits good in the different circumstances.
- Optometrists are entrepreneurs, to keep them happy the service needs to be directly or indirectly profitable for them.
- The ease of use and implementation are important for all the parties and determine the success of the service.



3. Healthcare market

In this chapter we look from a more macro view at the Ksyos ophthalmology service. We look at the willingness to adopt new technologies in the healthcare market, the financial structure of the healthcare market, important values in the healthcare sector and new upcoming technologies that could have an impact on the ophthalmology market.

3.1 AI in Healthcare market



The healthcare market is a difficult market to introduce new technologies there are strict workflows and strong hierarchies. Several studies dived into this field to figure out the best way to introduce new technical products in this market, and to design products that will be adopted in this market.

The potential of AI in healthcare is big. AI can deliver faster care, deliver more personalized care, can reduce the high costs of the healthcare and can shorten the waiting times (Park, 2019). However the introduction of AI also has some other effects, like Complex organizational changes, changes in hierarchies and communication with clients and within the organization, and resistance among clinicians. Clinicians could have fears of losing their job to an AI machine, have fear of having to learn new complex skills or have fears about trusting a black box.

The accuracy of an AI system in healthcare is the most important part. The clinicians need to rely on the outcomes the system gives. In some cases this could be difficult because clinicians use more info than can be retrieved from data alone to make their decision (Hartwood, 2003). That is why in these cases their always need to be a human in the loop.

However to create an algorithm that will be used effectively the physical and social context is much more important than just the prediction accuracy. To make a system that will be used, the system need to be designed as an integrated experience (Yang, 2019). Waghlikar created four requirements that a well adopted medical tool should include, besides a high prediction accuracy (Waghlikar, 2011). The tool should be well adopted to the workflow of the clinicians, The tool should be easy to use for the targeted clinicians and the tool should be able to explain why certain decisions are made.

3.2 Dutch healthcare system



Ksyos is a healthcare institute in the Netherlands this means they are paid by the Dutch healthcare system. This paragraph will give a little overview of the whole healthcare system and the part where the income of Ksyos ophthalmology is generated. The Dutch healthcare system is regulated by five laws, these laws determine who is responsible for providing what kind of care.

The Zorgverzekerings wet (Zvw) regulates the responsibilities for the curative care. The Wet langdurige zorg (Wlz) regulates the more demanding (24/7) care. The Wet maatschappelijke ondersteuning (Wmo) regulates the care that supports people to participate better in society. The Jeugdwet regulates care for children and the wet publieke gezondheid (Wpg) regulates big care programs for all citizens.

The Ksyos ophthalmology services like fundus screening and General Ophthalmology Examination are based on the Zorgverzekerings law. Under this law the health insurance companies are responsible for purchasing the health care. Under other laws like Jeugdwet, Wmo and the Wpg municipalities have this responsibility. The Zorgverzekerings law divides the market into three key players: the private individual, the health purchaser and the health provider. These three players create three markets the healthcare insurance market, healthcare provision market and the purchase and sales market for healthcare (figure 3.1). Competition in these three markets keeps the costs of the healthcare low.

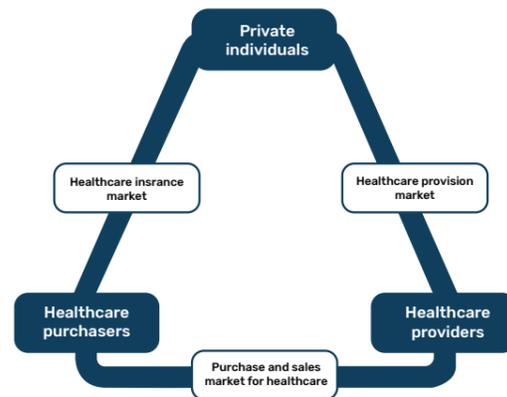


Figure 3.1. The three markets, the healthcare insurance market, the healthcare provision market and the purchase and sales market for healthcare.

healthcare providers

Healthcare providers are organizations that provide healthcare for example hospitals, UMC's, private clinics or zbc's. Ksyos is also a healthcare provider. The healthcare providers need to compete on the healthcare provision market to attract private individuals to use their provided care. Private individuals are free to choose their GP or dentist, but for secondary care they first need to be checked by a GP. The GP serves as a gate keeper and decides what kind of care the patient needs. For the healthcare providers it is important the GP knows about their existence and capabilities. The healthcare providers also need to compete in the purchase and sales market for healthcare. They need to negotiate with the health purchasers to get as much money for their service as possible.

Health purchasers

The health purchasers are health insurance companies. They have the responsibility to deliver care to the private individuals. They have to purchase this healthcare in the purchase and sales market for healthcare. They have to negotiate with the Healthcare providers to buy qualitative healthcare for a low price. They also have to compete with other health purchasers on the healthcare insurance market. At the end of each year the private individuals can switch between health purchaser. The health purchaser wants to attract good/healthy private individuals, but is also obligated by law to accept bad/unhealthy private individuals. Currently there are four big players in the health purchase market Achmea, VGZ, CZ and Menzis, they got about 88% of the market (Figure 3.2).



Figure 3.2. The health insurers in the Netherlands by amount of customers

Private individuals

The private individual is the one who brings money into the healthcare system. He is obligated by law to get a health insurance, and pays on average 5.720 euros per year for healthcare. He pays 1.362 euros nominal premium, 1.750 income related contribution, 1.412 taxes, 1.199 premium for the Wlz also supported by health insurers and 378 euro excess when he uses care. People with less money are supported by the government with a care allowance of 381 euro (figure 3.3). When insured the private individual can get all the care he needs. As discussed, the private individual first needs to go to the GP (Wessels, 2018), the GP decides the next step in the care program. For secondary care like a Ksyos General Ophthalmology Examination, the private individual needs to pay excess. When the limit of the excess is reached all the care is free. In the next paragraph we go deeper in on the money streams inside the primary and how fundus screening is payed.

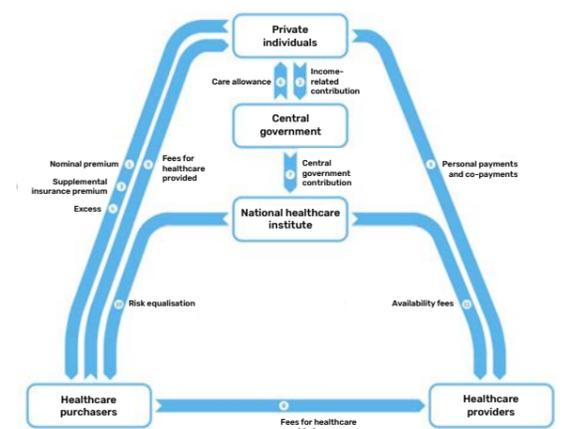


Figure 3.3. Money streams in the healthcare sector

3.3 Funding Ksyos ophthalmology



Figure 3.4. Four stages of the healthcare structure in the Netherlands

Patient path healthcare system

The healthcare for the patient is separated in four stages (Figure 3.4). The first stage is the zero-care stage, also called selfcare. When you have a headache, you do not go immediately to the GP but you get some medicine yourself at the pharmacy or take some rest. The second stage is the primary care stage. The GP, the dentists and the physiotherapist are examples of primary care. These are people who provide basic care and serve as a gatekeeper for the healthcare system. You do not need a reference and there are no premiums payments required. The third stage is the secondary care, these

are medical specialists who are expert in a certain area and often work in hospitals or clinics. Or psychologists who provide mental care usually at the ggz. For this care you need a reference from your GP and there are premiums payments required. The fourth step is the tertiary care, this is for people who need longer hospital care like disabled care, elderly care and rehabilitation. This type of care is covered by another law the law Langdurige zorg. Most services Ksyos provides are secondary care like the General Ophthalmology Examination. But the fundus scan service is primary care.



Figure 3.5. Three segments that determine the income of a GP.

Basic segment

The income of a general practitioner is based on three segments (figure 3.5). The first segment is the basic segment this is money they receive for basic tasks. They get a subscription fee from the health insurer for every patient that is subscribed to their general practice. They get paid for every consult they have. They receive extra money for N&I operations, these are formally secondary care operations that through extra training the GP is capable of doing. For example, taking an ECG. There is also a compensation payment for general practice in disadvantaged neighborhoods. Because they can have less patients because their patients go more often to the GP.

Keten zorg

The second segment is the keten zorg. These are payments the GP receives for patients with chronic diseases that take up a lot of time from the GP like diabetic mellitus, COPD and asthma. To deliver the best care to these patients general practitioner operate collectively in zorggroepen (care groups). A zorggroep determines for each disease what kind of care a patient needs. For example, a diabetic mellitus patient needs a every year a checkup by the GP, needs to go four times a year to the dietician, once a year needs to take a fundus photo,... etc (see figure 3.6). The zorggroep then collectively purchases the care they are not capable to deliver themselves from other health providers. For example, taking fundus pictures is purchased by Ksyos. This means that fundus picture taking is primary care and that patients do not have to pay excess.

Keten DBC	1x Check up GP
	3x Check up GP assistant
	1x fundus photo
	1x feet exam
	4x dietician
	4x hba1c measurement

Figure 3.6. Care that is included in the diabetic ketenzorg.

Innovation

The third segment is for innovations, this segment is used when a GP wants to test for example a new diagnosis device that is not covered by the other segments. The GP can ask the insurer through the third segment for financial support to test this new equipment.

General Ophthalmology Examination

When the GP has a patient with non-accurate eye problems, he can send him to Ksyos for a General Ophthalmology Examination. In this case Ksyos operates as a normal secondary care provider, the costs of the examination can claimed from the health insurer. The costs for the patient are determined on the negotiations between Ksyos and the health insurers. Patients of insures Achmea, VGZ, Eno, ASR and Eucare do not have to pay excess for this service in 2021. Patients of insures CZ, Mensis, Zorg en zekerheid and dsw need to pay around 60 euros excess (except DSW they need to pay 120 euro).

3.4 Values in healthcare



When designing for the healthcare sector it is important to understand the existing values. The association Zorgverzekeraars Nederland has done a research on the most important values that exist in the Dutch healthcare sector (De Argumentenfabriek, 2017). For this research they interviewed more than 200 people, the answers were clustered in collaboration with the Argumentenfabriek into nine value clusters. The clusters consist of six moral value clusters (three idealistic values and three social values) and three more practical values. all the cluster are showed in figure 3.7 (The complete overview of the different clusters can be found in appendix A1).

Freedom

The cluster freedom consists of three values: “zelfbeschikking”, “profecionele autonomie” and “privacy”. “zelfbeschikking” is a value important to the patient, it means that he has influence on the next step in the care path. It is important for the patient to be informed well, and participate in a shared decision-making process with the health provider. “profecionele autonomie” is a value important to the health providers, they are well educated and are in close contact with the patient. They want a little bit of freedom to decide what the best next step in the care path would be. “privacy” is an important value for the patient and the heath provider, the information shared by the patient need to stay private at all time.

Justice

The value cluster justice has a little contradiction, People think it is important that everyone is treated equal in healthcare and gets the healthcare they need. The strongest shoulders carry the heaviest loads.

But because of the rising healthcare costs there are new values entering this cluster like “wederkeerigheid”. People with a healthier lifestyle should be rewarded, and people who pay a lot less should not get unlimited care.

purity

This cluster has a couple of values that are important for certain groups in the Netherlands. For example, values like “Heiligheid” and “zuiverheid” play an important role for some patients. For them it is important that people should not decide about life or death, and that people can decide themselves if they want to get a vaccination or not.

loyalty

Healthcare is something that we as a society want to arrange together, the term “saamenhorigheid” represents this value. The value “trots” is one that is important for health providers, they feel proud of the beautiful job they have.

Hierarchy

This cluster looks at the different values that play a role in hierarchy. “autoriteit” is an important value for patients and health providers. Patients want to put their faith in the hands of a specialist. For health providers it is important their expertise is acknowledged. “traditie” plays also an important role in the healthcare sector, health professionals like to stick to proven techniques. When you want to introduce something new it is important to keep the elements that are valuable in the eyes of the healthcare professional. “traditie” is also important for patients they want to go to the same hospital their child is born and their parents died. This hospital gives them a feeling of trust.

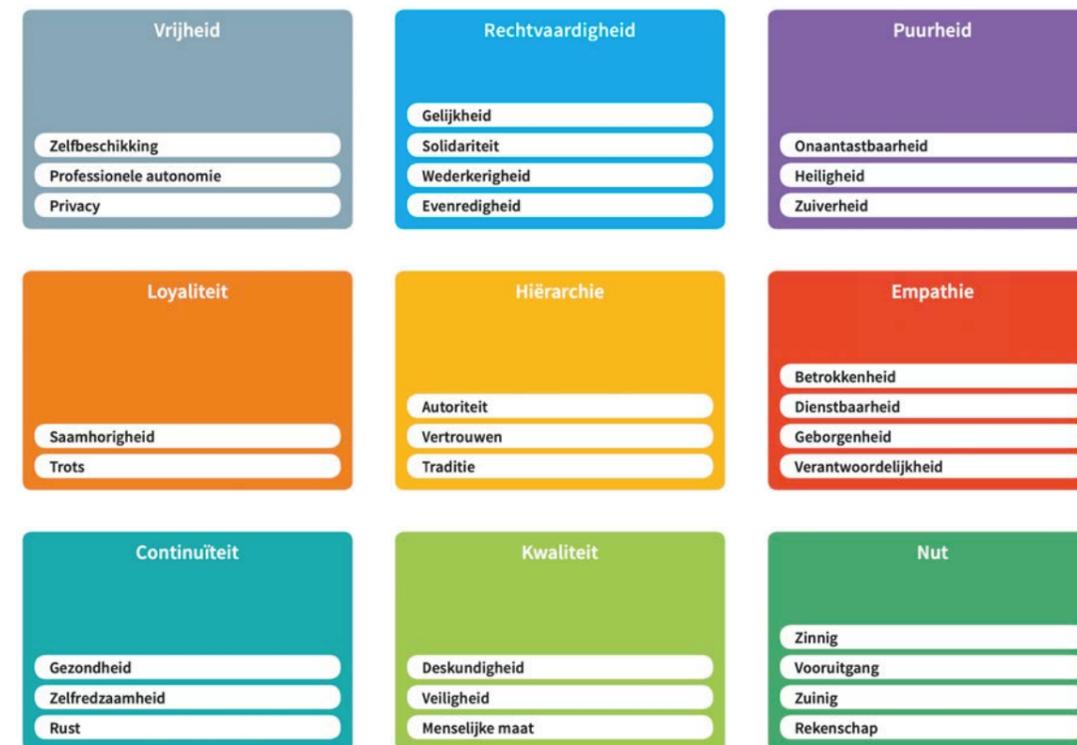


Figure 3.7. Values that play an important role in the healthcare based on clusters.

Empathy

Of course, empathy plays an important role in healthcare. For the patient it is important someone listens to their problem (value: “betrokkenheid”). The care for the patient is the most important value in the healthcare sector (value: “dienstbaarheid”).

Continuity

This cluster is about a more practical value continuity. The healthcare enables people to live a healthy live. If this is not possible a value that is important for patients is “zelfredzaamheid”. This means that the patient wants to keep participating in society, and the healthcare should support this wish.

Quality

For health providers the value “deskundigheid” is important. They want to help the patient the right way, and when they do not know something for sure they ask a more experienced colleague. “veiligheid” is also important value, for health providers it is important that certain protocols are followed.

usefulness

These values are about using the limited resources the healthcare has in the right way. Innovation is important, especially when you can do more with less money.

3.5 Retinopathy screening market



A retinopathy screening program is not everywhere in the Netherlands the same. There are different structures of the service based on the arrangements the care groups have made with their partners (Figure 3.8).

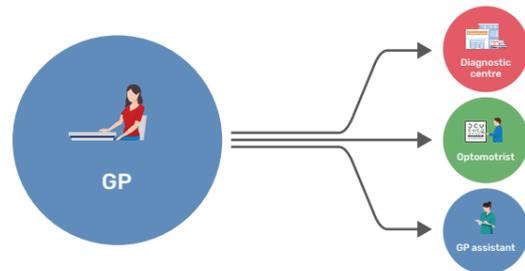


Figure 3.8. Different locations a GP can send a diabetic patient to do a retinopathy screening. A diagnostic centre, an optometrist and a GP assistant

Optometrist

The first structure only involves an optometrist (figure 3.9). The GP reverse patients with diabetics every 2-3 years to an ophthalmologist. The ophthalmologist will look at the visus and the eye pressure and takes a fundus picture. He will immediately grade the fundus picture and discuss the results with the patient. The results of the screening will be sent back to the GP.



Figure 3.9. The optometrist will take the fundus picture himself and then grades the fundus picture.

Medical diagnostic centre

The second structure also involves a medical diagnostic centre (figure 3.10), this is a place often close to a hospital. In a medical diagnostic centre people do pre-work for

diagnoses like taking blood samples or making fundus pictures. The pictures will be sent to an optometrist and he will grade the pictures. The results of the screening will be sent to the GP who will discuss the results with the patient.



Figure 3.10. The fundus picture is made at a medical diagnostic center and sent to an optometrist. At the optometrist the pictures will be graded.

GP assistant

In the third structure the care group decides to take the pictures themselves (figure 3.11). A GP can take the pictures in his own practice, or GPs can work together and choose one spot to take all the fundus pictures. The grading of the pictures will still be done by an optometrist. He will send the results back to the GP.

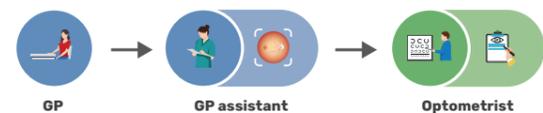


Figure 3.11. The fundus picture is made at the GP office by an GP assistant. The picture will be sent to an optometrist, who will grade the picture.

3.6 Tech developments in healthcare



There are a couple of relevant developments in the healthcare sector that aim to make diagnoses more accessible.

Easee Visus test

Easee is a company who provides an online CE-certificated visus tests. A visus test is used to determine a patient's visual acuity. During the test the patient needs to read characters from a board or screen, based on the answers the visual acuity can be determined. For a correct result it is important the system knows how big the characters appear on the screen and what the distance between the patient and the screen is. To calibrate the screen size the patient needs to change the size of a box on the screen to match a regular bank card. The distance between the screen and the patient is explained by number of required footsteps (figure 3.12).



Figure 3.12. a) bank card used to determine size screen b) footsteps used to determine distance from screen.

When the test starts the patient sees a character on the laptop screen and can use his phone to pick the right character (fig. 3.13).

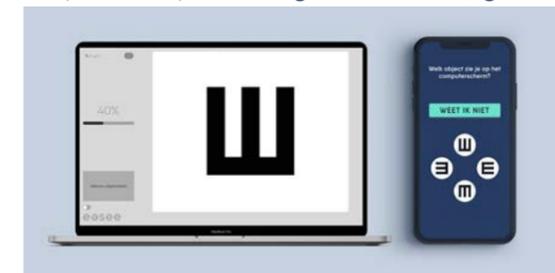


Figure 3.13. Phone and laptop while doing the test.

Google Derm assist

One party that is planning to introduce an image-based consumer AI health service is Google. They plan to rollout this fall the Google derm assist service. The service makes use of the camera of the mobile phone of the patient. The patient takes three pictures of a spot on the skin that concerns them and enters some additional information. The AI algorithm predicts what kind of diseases this spot could be. From of the list of different diseases the patient can pick one to get more details about for example severity or treatment options (figure 3.14).

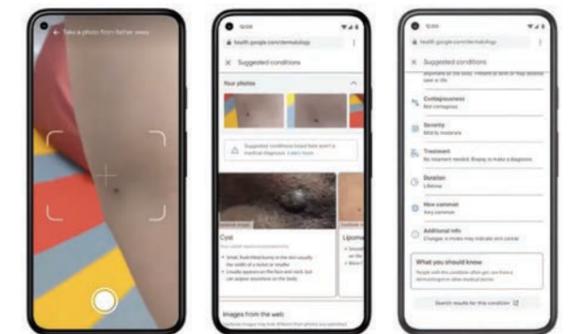


Figure 3.14. Example how Google derm assist will look like

I discussed this new service with different ophthalmologists, they indicate that this would not be the desired direction. The usefulness of these kind of services is dependent on a low false positive rate. When this rate is too high there will be lots of patients who go unnecessary to the specialist. This will damage the acceptance of specialists from these kinds of services. The general practitioner will also lose faith in these kinds of services when it only generates lots of unnecessary panic. Since the proposed Google service introduces a list of possible diseases indicates that the service does not know for sure if it is that



3.7 Optician market



In comparison to other non-food stores the optician still makes a lot of profit in this internet era. In most shopping centres there are still multiple opticians competing with each other. The reason behind these profits are the big margins these opticians make on their glasses. The profit margins of an optician are 9.6 percent, the margin for other non-food stores is 2.8 percent according to research agency Panteia (Hermandes, 2017). This in combination with the growing demand for glasses because of population aging and the amount of screen time makes this an interesting market for new entrances. In this paragraph we look at the different type of opticians and how they distinguish themselves from each other.

individual opticians

The individual opticians are often focused on the wealthier customers. They distinguish themselves from the big optical chains by providing better services. For example, they hire optometrists who have more knowledge about the eye. These optometrists could do complex eye screenings and translate this information into valuable insights. They also are connected to ophthalmologist through services like Ksyos Ophthalmology. This direct link can give the customer the feeling that their eyes are in good hands.

Big optical chains

The big optical chains like Hans Anders, Specsavers, Eyewish and Pearl compete with each other through advertisements. They try to lure customers to their stores by promising all sorts of extras like a free second set of glasses. They often do not

hire optometrists but opticians. The optician can measure the visus of a customer, this is important to pick the right glasses. They sometimes do have a fundus camera to do more advanced measurements but they are not able to interpret these pictures.

Drugstore

The high margins of optician are also noticed by drugstores. These stores are now entering the market of selling glasses. Drugstores like Etos and Da do this in cooperation with Eyelove. Eyelove use a shop in shop structure, there are no optometrists or opticians in this store. The employees of the drugstore are taught how to measure the visus of a customer. Since Eyelove has low employee costs and overhead costs, the price of the glasses is low. The profit of the glasses is split between the drugstore and Eyelove.

Online

As discussed in the last paragraph it is now possible to measure the visus at home. This makes it a lot easier for selling glasses online. There are several companies now focus on selling glasses online.

3.8 Screening programs



For a lot of diseases, the detection stage is key for better and cheaper treatment. That's why there are in the Netherlands big population screening programs. The goal of this screening programs to screen a huge part of the population by performing these screenings close to peoples home.

Population screening

The RIVM is responsible for a couple of big disease diagnosis programs like breast cancer and colorectal cancer. The goal of these programs is to have an as high as possible attendance rate. For breast cancer, they use mobile diagnosis centers that park close to people's homes (figure 3.15). With this program, they reach an attendance rate of 75%. A relatively new program started in 2014 diagnoses colorectal cancer. This diagnosis takes place at people's homes. They have to stick an object three times in their poo and send this object with a letter to a lab. This method with a letter is a success the attendance rate is 73% (Van Haaren, 2020).



Figure 3.15, a) A mobile diagnosis centers for breast cancer diagnosis b) A letter for a colorectal cancer diagnosis.nosis b) A letter for a

Consultatiebureau

In the Netherlands there are only population eye screenings for children, the goal of these screenings is to discover eye problems at an early stage (figure 3.16). For example, a lazy eye can be treated effectively when it is discovered in an early stage. When people get older there are no population screenings for discovering diseases like glaucoma or

cataract. Besides of course the diabetic people who are screened for retinopathy.



Figure 3.16, Consultatiebureau screening

75+ CBR check

There is however one sort of population screening 75+ CBR check. People who are older than 75 who want to extend their drivers license need to fill in a health form. When they indicate in this form that they have problems with their visual field. A doctor will do a small eye examination with a visus test. This could be a good starting location for an AI population screening program. However, a glaucoma specialist indicated that this is already too late for a glaucoma screening. It will be better if people from age 55 will be screened.

Conclusion

The general practitioner is the one who is responsible for providing the diabetic care to the patient. This means the GP will be the main users of the AI service, he will use it to determine if their diabetic patients have developed retinopathy. The GP organizes this care in ketens. The new AI service should best be adapted to the needs of the different GP ketens.

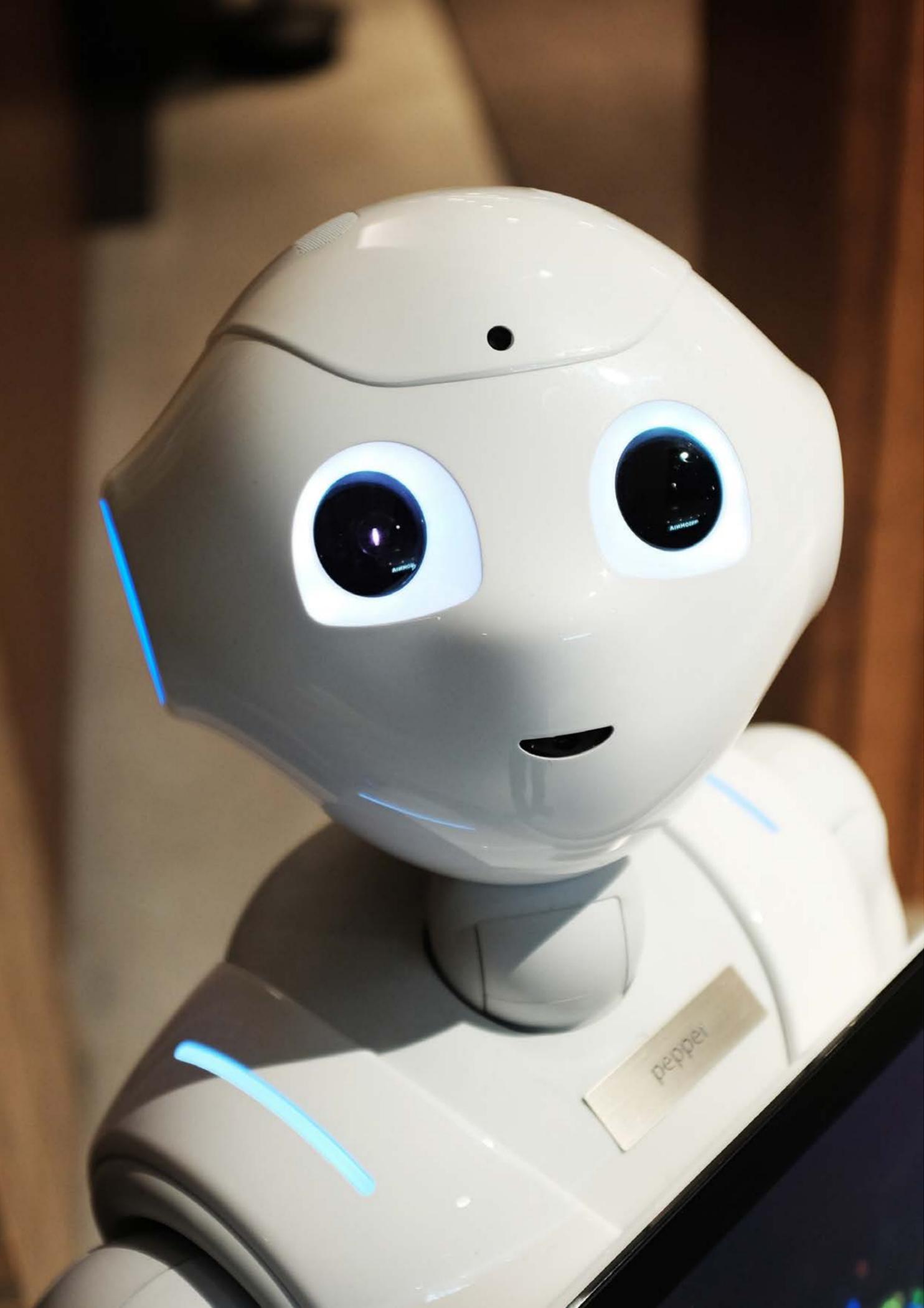
Tradition and empathy are important element in healthcare. The new AI service should keep the possibility for people to talk about their problems with someone. And the good parts of the current system should not change that much.

The new AI service should adapt itself to the changing optician sector. This could for example mean that the system needs to be used and understood by less schooled people.

The introduction of new AI systems for the public with high false positive rates it not a good development according to the different medical specialists. It is best to keep the false positive rate as low as possible for ophthalmologists.

Key insights

- Each GP keten is responsible to organize their own diabetic care. Each keten has their own requirements for a service based on the availability of ophthalmologists and optometrist in that area. It is best when the AI service can be adapted to those needs.
- The new AI service should keep the good elements of the current service. Tradition is important in healthcare and when you want to introduce something new you best keep the good elements of the current service.
- The optician sector, where most of the screenings are done right now, is changing. The introduction of online visus screenings will potentially stimulate internet sales and reduce the margins. This could lead to a need for providing better services at the lower budget opticians. This makes an AI service attractive. But it could also lead to premium opticians not be able to spare enough money anymore to provide the Ksyos ophthalmology service.
- In the AI service there should still be possibilities to talk about your problems because this is an important part of the healthcare experience.
- The location the screenings will take place in the new AI service should feel appropriate and traditional.
- For a successful implementation of the AI system the tool should be easy to use for the different clinicians and explain why certain decisions are made.



4. The algorithm

In this chapter we look shortly at the type of algorithm that is going to be used to develop the eye screening algorithm, and look at how Healthplus.AI is going to do this.



Ksyos is not developing the algorithm by itself. They do this in collaboration with their strategic partner healthplus.ai. This is a company specialized in developing algorithms for the healthcare sector. Ksyos will provide the data necessary to develop the algorithm and focus on how the algorithm best can be implemented. Healthplus.ai will sort the data based on the labels and train a neural network to be able to detect diabetic retinopathy.

To better understand what is possible with the algorithm it is useful to understand a little bit about how a CNN algorithm theoretical works and how Healthplus.ai will develop this CNN based neural network.

4.1 Convolutional neural networks



Artificial intelligence (AI) is a technique that enables computers to mimic human behaviour. Within the area of AI machine learning is a technique that enables a computer to learn without being explicitly programmed through neural networks. Deep learning is a subclass of machine learning that basically uses more neural network layers.

An often-used deep learning class to identify elements in pictures is a convolutional neural network (CNN). These neural networks can learn to see patterns in images by looking at the relations pixels have with their surrounding pixels. This helps to detect elements in pictures even when they are presented in different ways than in the training data.

To recognise patterns in an image CNN uses three techniques: a filter (Kernels), a ReLU activation functions and pooling. To explain the CNN network we will look at a simple example of a computer program that needs to distinguish an image of a cross from a circle.

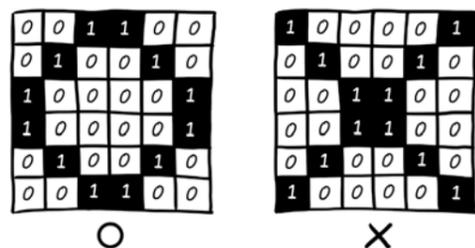


Figure 4.1, Black and white circle and cross from 6 by 6 pixels.

To find the patterns in the image CNN makes use of filters, these are small arrays of 3 by 3 pixels that look at the relation one pixel has with its surrounding pixels. The allocation of values in these filters is chosen randomly, but through training the most helpful filter will survive in the algorithm. In the example we look at a filter that can detect a diagonal line (figure 4.2). The filter is first placed in the top left corner (blue square) and the dot product of the two arrays is calculated. The value is then after subtraction from the bias (this is a value calculated when training the algorithm) placed in the top left corner of the feature map. The filter will be moved one pixel to the orange square and the next dot product will be calculated and placed on the second spot of the feature map.

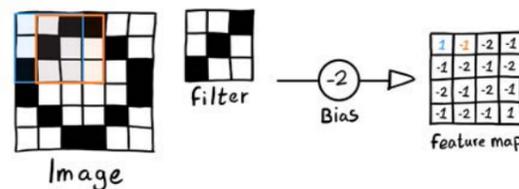


Figure 4.2, Diagonal filter creates feature map from image.

The feature map is often be normalised in CNN to make calculations less complicated. The ReLU activation function is usually used, this function (max(0,x)) will change all negative values to zero and pass through all positive values. This creates a new feature map with only positive values. In this case it shows clearly where the filter matches the image (Figure 4.3).

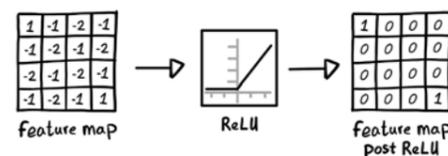


Figure 4.3, ReLU function normalizes feature map.

Pooling is used in CNN to reduce the dimensionality and lower the sensitivity towards small changes in the image. there are different types of pooling like mean pooling (take the mean value of the numbers in the selection) and max pooling (take the maximum value in the selection). In this case we use max pooling (figure 4.4).

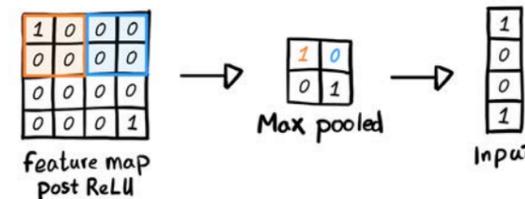


Figure 4.4, Feature map is translated in input data using max pooled.

Based on these input values a normal neural network can determine if this image is a cross or a circle (Figure 4.5). This normal neural network consists of weights, summations, biases and an activation functions. Weights and biases are usually in the connections between different knobs and consists of multiplications, adding and subtractions. The values of the weights and biases are calculated using back propagation. In this proces the error between the predicted value and the real value from the dataset will be minimised using derivatives and gradient descent. In this case there is no error, the neural network gives a prediction of 1 for the circle and 0 for the cross. This means the algorithm thinks this picture is a circle.

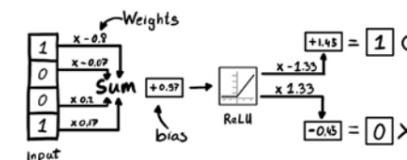


Figure 4.5, Normal algorithm uses weights, biases, and sums to determine if the image is a cross or a circle.

When applying the same CNN for a picture of a cross, the prediction is 1 for the cross and 0 for the circle see figure 4.6.

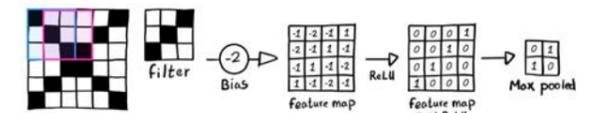


Figure 4.6, The same algorithm is also able to recognize a cross.

When the image is slightly moved to the right, the algorithm is still able to recognise the pattern. And gives the right prediction of the image (Figure 4.7).

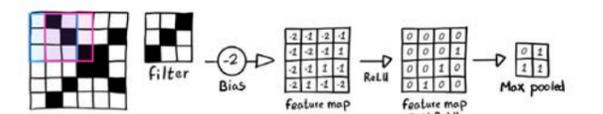


Figure 4.7, Because of pooling the algorithm is still able to detect the cross when it is slightly moved.

This is the most simple version of a CNN, in reality the networks combine much more filters an have more layers to determine more complex shapes. But the principals are the same, CNN identify objects in pictures by focusing of patterns in the pictures. It uses filters to find out about the relation between pixels and uses pooling to reduces the dimensionality and lower the sensitivity

4.2 Developing the algorithm

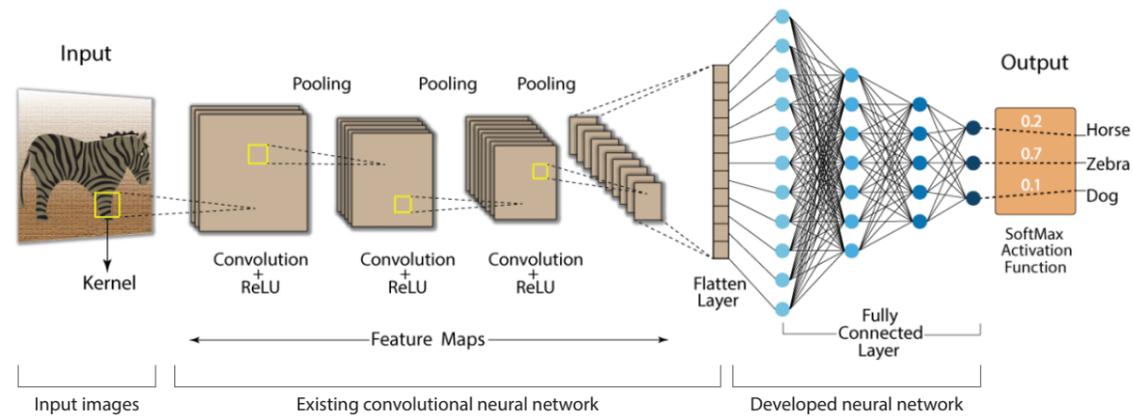


Figure 4.8. How healthplus.ai the eye disease algorithm will make.

In this paragraph we look briefly at how the algorithm will be developed. And what is possible with the data from Ksyos.

Developing the network

Developing a convolutional neural network from scratch takes up a lot of time. That is why often existing neural networks are used as a starting point. These existing CNN networks are capable of detecting all kinds of patterns. The output is often a flattened line of values. These values are used as an input of a normal neural network. This second network is the one that will be developed to detect eye diseases (Figure 4.8).

There are two ways to manipulate the outcome of the neural network. You can tweak the second neural network or you can tweak the input image. For example, when you want to compensate for different colors in the fundus pictures you can filter the input images a little bit so the two pictures look more the same.

You cannot focus the algorithm manually on

a specific part of the image. A CNN network does this automatically, the network will recognize all the patterns in the picture. However, in the to be developed second neural network you can play with the input values that correspond with this specific area.

In the whole process of developing the algorithm labeling the data is the most important step. Incorrectly labeled data will later in the process results in a lot of problems. After labeling the data correctly trainings are performed on small data sets. When these small datasets receive positive results, training with a larger data set will be performed. This takes up a lot of computing power.

Confusion matrix

To show how good the model is in sorting an object in specific class a confusion matrix is used. The confusion matrix shows the true positives, true negatives, false positives and false negatives. The true positives and true negatives are the objects that that are

predicted correctly as positive or negative. The false positives and false negatives are predicted incorrectly see figure 4.9.

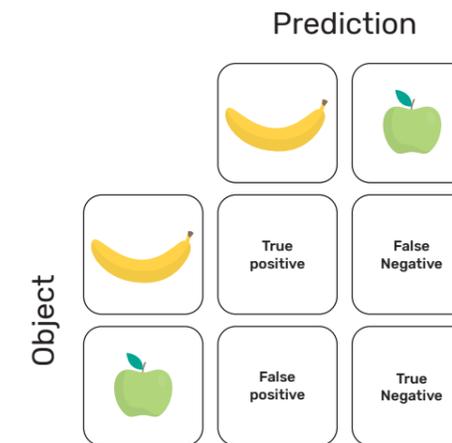


Figure 4.9. Overview of terminology AI development.

Precision and recall say something about how good the model is in predicting one class and in predicting the other class. When there are almost no false positives the precision is high, when there are no false negatives, the recall is high. These two values depend on each other. The F1 value is a combination of the precision and the recall and shows how well the algorithm overall performs.

Ksyos data

Not all data used to train the algorithm divides diabetic retinopathy in the stages mentioned before. When Ksyos started with diabetic retinopathy screenings in 2008 the optometrist could only indicate if the patient had diabetic retinopathy or not. Since 2014 the optometrists where ask to rate diabetic retinopathy based on a scale from low to high. However the requirements for each stage where unclear. Since 2017 the new scale is introduced as described in chapter

1.2, every stage has clear guidelines which make the screenings easier and consistent. An overview of the total and supervised data is shown in table 4.1.

Description	Requests	Images
Supervised retinopathy	19.234	88.000
Old method	18.800	86.000
New method	434	2.000
Total graded retinopathy	293.800	1.358.500
Old method	281.600	1.300.000
New method	12.200	58.500

Table 4.1. Dataset of Ksyos ophthalmology.

There is not as much data in the Ksyos data set of the more severe stages of retinopathy. When the retinopathy reaches a certain severity, the patient will be reverred to the ophthalmologist. At the ophthalmologist, the fundus pictures won't be uploaded to the ksyos data set anymore.

Key insights

- The new AI system could either be optimized for precision, recall or F1 based on the needs from the medical specialists
- Not all ksyos gradings are done according to the same guidelines, this could have influence on how the model will be trained and based on what categories it can decide if people need to be reverred to the ophthalmologist or not.
- When the AI system won't detect retinopathy by certain people the input image can be filtered to compensate for this.

5. Workflow

In this chapter we look deeper into the different stakeholders. How their workflow looks like and how they view the new AI system

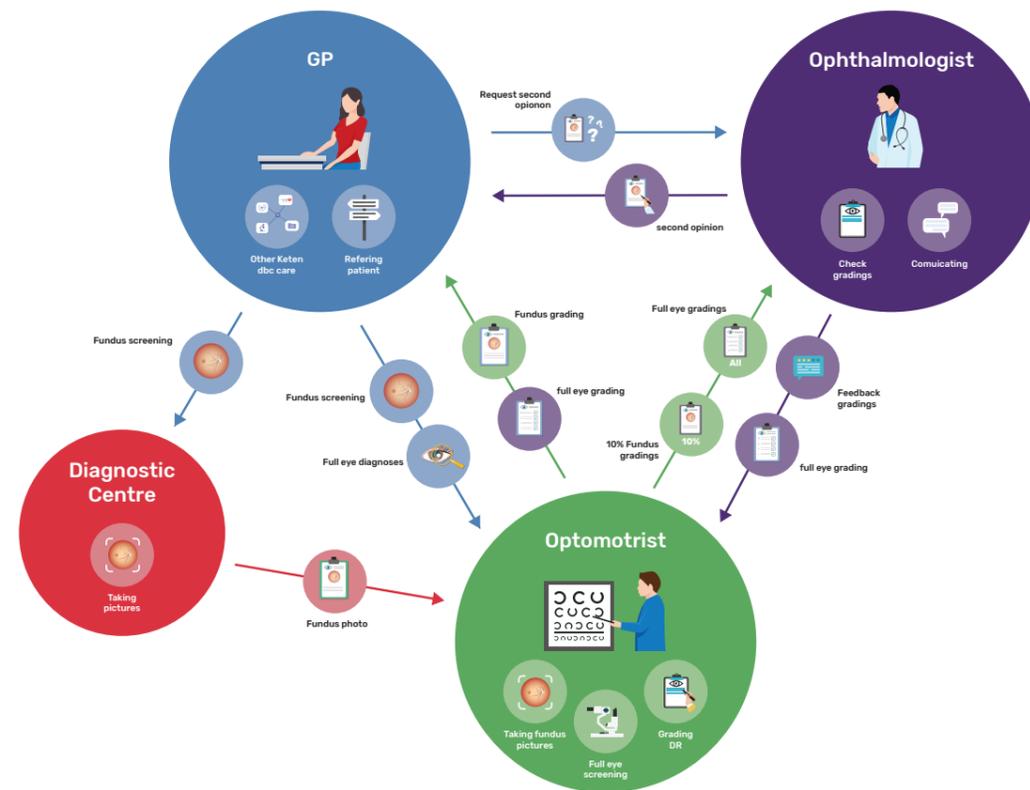


Figure 5.1, Overview of how the different stakeholders work together in the current ksyos ophthalmology service.

The current Ksyos ophthalmology service consists of four big players. The GP who refers diabetic people to the Optometrist or a diagnostic centre. The diagnostic centre that takes fundus pictures and sent them to the optometrist. The optometrist who takes and grades fundus pictures. And the ophthalmologist who checks a percentage of the gradings of the optometrist.

To get a better picture about the workflow of the different stakeholders and their opinions about Ksyos and AI. I interviewed the different stakeholders. In this paragraphs the conclusions of those interviews are presented.





5.1 Optometrist



The optometrist plays an important role in the current Ksyos ophthalmology service. For this research five optometrists are interviewed to get a better understanding about what they need from Ksyos, how their workflow looks like and what their opinion is about AI.

Collaborating with Ksyos.

All optometrists interviewed during this research indicated that there was no business case for diabetic retinopathy screenings. They receive around 17 euros per screening and one screening takes about 15-40 minutes. This is not enough to make profit from providing this service.

There are two big reasons why optometrists do participate in the fundus screen program, to better integrate into the healthcare network and to provide a better service to their customers.

The Ksyos screening program improves the communication between the GP, optometrists and ophthalmologist. This helped the GP and the ophthalmologist to be more aware of the capabilities of optometrists. Since the GP trusts the quality of the diagnoses of the optometrist, he will send more people with eye problems like glaucoma or cataract to the optometrist. These more advanced screenings are more fun for the optometrist and are also more lucrative.

Better service is another reason why optometrists do participate in the fundus screening program. The scans and the other available equipment show the customers their expertise in eye care. This improves the satisfaction of their current customers.

Fundus screening could also lead to new customers because patients of other opticians are referred to them. This could help increasing the customer base and more sales but in reality, this happens not that often. Diabetic patients (type 2) are in general not the wealthiest patients, and the opticians who have the expensive equipment to do a fundus scan are usually the more luxurious opticians.

Fundus screening

Before taking a fundus picture all optometrists first measure the refraction of the eyes and the eye pressure. Some optometrists use two different machines others have one machine who performs the two measurements simultaneously. After these measurements the two fundus pictures of each eye are taken. The picture appears on the device itself and in the camera software on the computer. The optometrist will examine the pictures on diabetic retinopathy and other potential problems. This examination takes about 10-60 seconds. He will discuss the results with the patient and enter the data first into their own documentation system. Depending on the optometrist he enters the data into the Ksyos platform directly after the patient left or he enters the data of all the patients into the Ksyos platform at the end of the day.

Taking a good fundus picture is influenced by the size of the pupil. When the size is too small the patient needs mydriatic drops to increase the size of the pupil. Not everyone needs eye droplets but the older people are the smaller the pupils will be. Most of the diabetic patients who need to do a fundus scan are relatively old. The type camera also has influence on if you need mydriatic drops

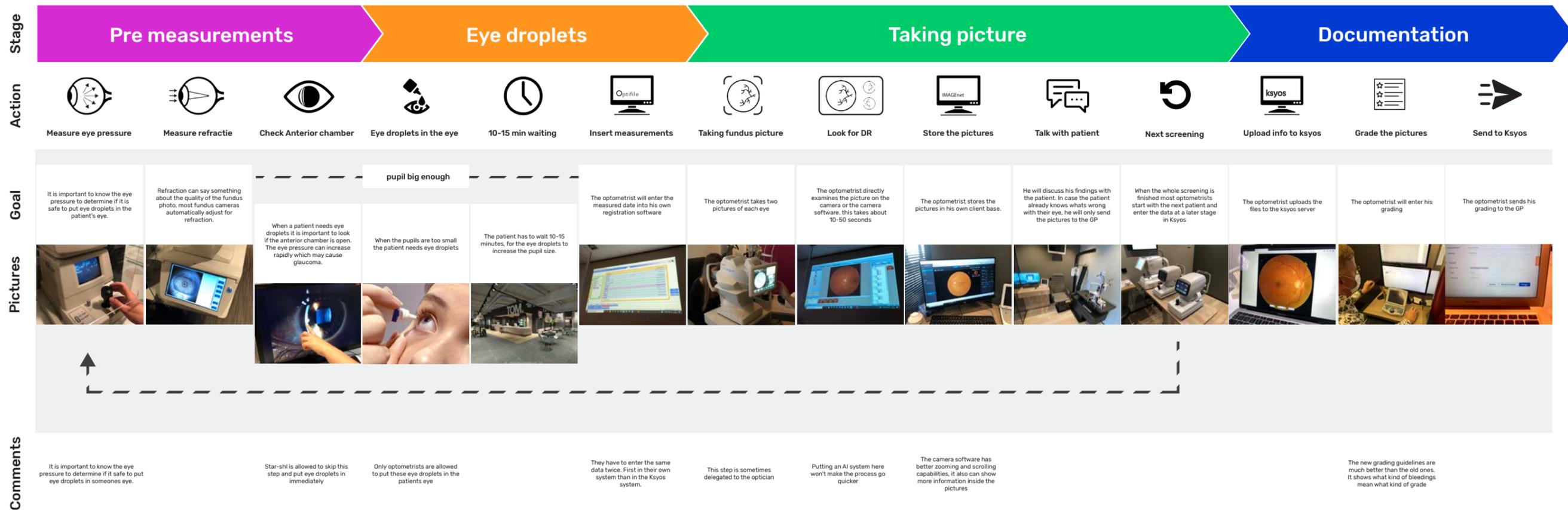


Figure 5.2. Customer journey of retinopathy screening at the optometrist.

or not. With a good normal camera 30% of the people need mydriatic drops with a laser camera only 7% need mydriatic drops. The laser camera looks better also has its drawbacks (see chapter 1.5). When a patient needs eye droplets first the optometrists checks of the anterior chamber is open with a slit lamp. When this is the case he drops a pre dosed Tropicamide droplet in the eye. The patient then needs to wait 10-15 minutes.

The time the optometrist plans for the whole screening is 15-40 minutes. This time is based on the fact that sometimes people

need mydriatic drops. Most optometrist cluster the diabetic patients to create a flow for example 8 patients in 2 hours. Besides the fact that the screenings go fast the human interaction is important. The screenings are still some kind of promotion for the store.

Around 85% of all the patients that need a fundus screening have no diabetic retinopathy. Sometimes they do have other problems, in this case the optometrist starts an extra normal eye examination.

Artificial intelligence

The opinion of AI among optometrists is diverse. Some optometrists were aware of the opportunities of AI and saw potential in using the technique. For example, filtering people before sending them to an optometrist. This way the new AI system will improve the efficiency of the whole system and the optometrist can help the patients who need him. The AI system could also help by scanning more people like a bevolkingsonderzoek, this way more people with undiscovered eye problems can be helped. One optometrist saw the opportunity

of removing the optometrist out of the system and let opticians do the screening. But he also indicated that he is needed when the patient needs mydriatic drops, and when there is a real problem with the eyes.

Other optometrists were surprised and a little bit skeptical about the possibilities of AI. These people need to be convinced about the capabilities of AI. They indicated that this feeling of distrust could be triggered by the term AI, for example they did trust their other equipment that also made prediction in a way that is unclear to them.

5.2 Ophthalmologist



The ophthalmologist is a physician specialized in the ophthalmology. In the current service of Ksyos the role of the ophthalmologist is to check and validate the diagnoses made by the optometrists. I interviewed three ophthalmologists to get a better overview of the current service Ksyos provides and to discuss their view on AI.

Ksyos service

The service Ksyos provides in combination with other initiatives has helped the ophthalmology in the Netherlands a lot. 15 years ago, all diabetic patients had to go every 1-2 years to the ophthalmologist. This made up a large part of the daily operations of an ophthalmologist and causes long waiting times. With the Ksyos service these preventive checkups are now done by optometrists. This saves a lot of time for the ophthalmologists. Since the number of diabetic patients has increased it will not be possible anymore to do it the old way. Right now, an ophthalmologist has to validate 60 fundus gradings a week. He has no time to also take the fundus pictures from all these 60 people.

Workflow

The workflow for ksyos is simple, the ophthalmologist receives a report with data of some measurements performed by an optometrist including an advice for the next step. The ophthalmologist looks through this report and approves or overrules this advice. Assessing this report takes about 3-5 minutes. In hospitals the ophthalmologists often divide the task over the different ophthalmologists. This means every day one ophthalmologist gets the job of reviewing all the incoming screenings.

Artificial intelligence

Right now, there are no screening programs besides the diabetic retinopathy screening for diabetic people. This means that most of the eye diseases that are asymptomatic in the beginning stage like cataract and glaucoma are only discovered by accident. We often have people with severe eye problems that we could have helped better when the disease was discovered in an earlier stage. For diagnosing eye diseases AI could be really beneficial. A lot of optometrists are not always capable of detecting a complex disease like glaucoma. With AI they but also less schooled people will be able to perform a glaucoma diagnosing.

AI can be used for a more widespread screening program. Ideal will be when everyone who gets 50 will be screened on several eye diseases. AI could make such a screening a lot cheaper. But I think it is still too expensive, in society prevention of vision loss is not as important as prevention of death. There is one eye test for adults, the 75+ test. This test is only for people who have a drivers license but this could be a good starting point. However, for glaucoma this is a little too late.

For the AI system to be successful the false positive rate is important. When the false positive rate is too high ophthalmologist will lose faith in the system. The ophthalmologists usually already have a long list of waiting patients. When a big percentage of the people who are referred by AI do not actually need care the ophthalmologist will stop use the services,

Another important question is what information do you provide to the patient.

The patient has the right to know everything, but it is not always better to tell them everything. For example, for people making a decision based on percentages is difficult. When someone has 5% change of glaucoma this patient probably wants to go to an ophthalmologist to check this. It is better to provide simple short information and focus on a low false positive rate.

What google does with the dermatologist will give the patient information without understanding the whole context of the disease. This could lead to an overload of people going to the general practitioner with potential diseases. This could also lead to backlash from the GP's.

Equipment

The evolution of fundus cameras goes quickly. In the near future full non-dilated fundus cameras will enter the market. This makes it possible for more people to take fundus pictures. Right now, there is still a risk of instant glaucoma, but this chance is really small. When you put mydriatic drops in the eyes of all the people in the Netherlands only 50 people will develop instant glaucoma. Preventing this is difficult, it is important for the optometrist to recognize instant glaucoma and send this person immediately to the hospital.

5.3 General practitioner



The General practitioner is the one who is responsible for the care of diabetic patients. These patients have to go once every 4 - 5 months to the GP assistant for a regular diabetic checkup. The GP assistant will measure certain metrics like blood pressure, weight and sugar levels. For a fundus picture they often refer to an optician. It could be that in the future GPs will take this picture themselves. But they indicated that they will never spend 10.000 euro on a fundus camera. I interviewed a general practitioner to get a better understanding of their needs according to the Ksyos ophthalmology service and how they look to potential future scenarios.

Ksyos service

For the general practitioner the only thing that is important is to get an answer to their care question. They sent their diabetic patient to an optometrist with the question does this person have diabetic retinopathy. The answer they want is yes or no. Or maybe even send the patient to an ophthalmologist or new screening in three years. The other information they currently receive like the vision and the eye pressure are not relevant to them and unnecessary. Even the fundus picture does not add any value for them.

Conclusion

The new AI service should still help the optician store to provide a good service to their customers. The AI service will mean that also optician stores with less educated employees could perform these types of screenings.

For the ophthalmologists the AI service should have a low false positive rate, they do not want more unneeded patients. For the GP it is important the AI services does not give too much complicated information. They prefer a simple answer to their care question.

Key insights

- The AI services should help opticians or optometrists to provide a better service to their customers.
- The new AI service won't help an optometrist in its current workflow. He detects the diseases within an instant, uploading the picture and run it through an AI system will take much longer.
- The AI system should have a low false positive rate, the ophthalmologist already has long waiting lists. He does not want a lot of new patients who actually do not have to go to the ophthalmologist.
- The AI services should not give too much unnecessary information to the general practitioner.
- When the GP assistant will take the fundus pictures in the AI service Ksyos should rent the camera to them because they will never spend 10.000 euros on a camera.



6. AI ethics

In this chapter we look deeper into the different stakeholders. How their workflow looks like and how they feel the new AI system

6.1 Morality



Morality says something about what is viewed as good and what is viewed as wrong in society. In this case we look at how people view choices made by artificial intelligent systems. And more specifically an AI system that diagnoses eye diseases.

Before saying something about the morality of AI it is important to understand the terms moral agent and moral status. A moral agent is someone or something that can be held responsible for its actions. Moral agency is often viewed as a scale, a grown-up has a high level of agency and a toddler a lower level of agency.

Moral status says something about the person or object affected by an action. How much value does this object have and what is the permissibility to sacrifice this object to reach a certain goal.

Not all AI can be viewed the same way there are two main types of AI, strong AI and weak AI. Strong AI has intelligence

in multiple domains, this looks more like human intelligence. Weak AI is designed to have intelligence in one specific domain, like screening fundus pictures to detect eye diseases.

The moral agency of weak AI is often viewed as limited; the AI system is seen as subservient to humans. The moral status of machines is the last couple of years slightly increasing but is still very low.

Our moral judgement is not based on rational thinking but on an automatic emotional reaction. These judgements are culturally based and influenced by your social groups. This means that these moral judgements are not everywhere on earth the same. However, there are a couple of moral dimensions that help to explore how we look at the morality of certain actions (Hidalgo, 2021). The five moral dimensions are harm, fairness, loyalty, authority and purity (figure 6.1).

HARM	FAIRNESS	LOYALTY	AUTHORITY	PURITY
harmful (-)	unjust (-)	disloyal (-)	disobedient (-)	indecent (-)
violent (-)	discriminatory (-)	traitor (-)	defiant (-)	obscene (-)
caring (+)	fair (+)	devoted (+)	lawful (+)	decent (+)
protective (+)	impartial (+)	loyal (+)	respectful (+)	virtuous (+)

Figure 6.1. The five moral dimensions: harm, fairness, loyalty, authority and purity

Based on these moral dimensions there are some parts that could cause moral judgement of the AI eye diagnoses system. Unfairness could play a role, there is a correspondence between skin pigmentation and the density of pigmentation in the retina (Silvar, 1967). This means the fundus photo of black people looks different than a fundus picture of caucasian people (figure 6.2). When the algorithm does not compensate well enough for this or is better at diagnosing Caucasian people than black people would cause an unfair system. This could lead to moral judgement of the AI system.

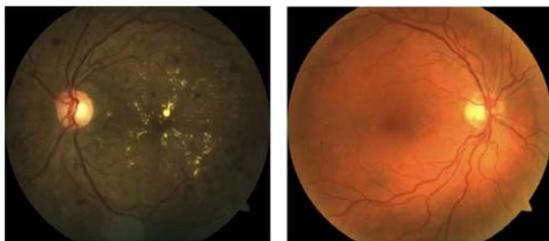


Figure 6.2, a) a fundus picture from someone with a lot of pigment b) a fundus picture of a Caucasian person.

Harm could also play a role when the AI system decides who should be revered to the ophthalmologist. To keep the acceptance rate of ophthalmologists high the false positive rate should be low, this means that you could miss people who should have been revered to the ophthalmologist. This could cause harm to these peoples eyes and could cause moral judgement of the AI system.

These moral dimensions determine partly if an action is viewed as morally correct. The most important part is the intention behind the action. For example, figure 6.3 shows two actions A and B. Action A did not cause any harm but had the intention to cause harm. Action B did cause harm but did not have the

intention to cause harm. You can see that action A even though there was no harm is viewed as much more morally wrong than action B. The intention behind the actions of a human being determines the moral judgement of people.

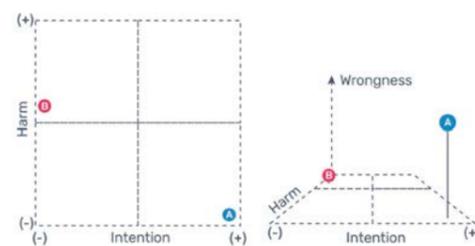


Figure 6.3, Influence of the intention of a person on the perceived wrongness.

These moral dimensions and intentions determine how we judge morality of actions. But there are differences in the way we judge humans in comparison to AI systems. César Hidalgo studied these differences, he looked at 60 different scenarios and compared how participants judged the human and the AI system.

When the action causes harm people are less forgiving to the AI system than to the human. They feel more connected to the human, and think the action of the human is much more morally correct. They often want the AI system to be replaced by a human.

On the other hand, when the action causes unfairness. People are judged more than the algorithm. They are very negative about humans who judge people unfair and view this as more morally incorrect.

Privacy

Privacy for storing and using fundus pictures could become a concern in the future. A fundus picture is unique to a person and can be used as biometric identification. Currently retinal identification is only used at highly secured locations like nuclear centers and weapon factories. It is the most secure biometric identification, Face, palm, fingerprint and iris recognition systems can all potentially be corrupted by plastic surgery (Köse, 2011). When more companies or governments will start using this kind of identification and make databases, the pictures cannot be anonymized anymore. This data could become valuable for hackers, and people could become less willing to give this data away.

Key insights

- The AI system could create unfair outcomes when the algorithm is not able to read fundus pictures from people with extremely less or more than standard pigmentation rates.
- The algorithm must prevent causing harm by using a too low false positive rate. The AI service as a whole needs to provide a way to also diagnose the diseases by these people.
- The transporting of data in future versions of the retinopathy service should potentially be better secured.



7. Synthesis

In this chapter the findings of the analysis are translated into a design direction for the to be developed AI service.

7.1 Synthesis

The synthesis can be seen as the bridge between the analysis phase and the ideation phase. The goal is to translate the different insights from the analysis into a problem definition and design goals for the to be developed service.

7.2 Problem

To prevent vision loss by eye diseases like glaucoma and retinopathy it is important to diagnose them on time. When you discover the disease too late the vision will be irreversibly be damaged. For this reason, diabetic people are screened preventively, but this cost a lot of money. Previously this group was screened every year now only every three years, all to save costs. For glaucoma are no preventive screening programs because the group is too diverse, but ophthalmologists indicated that it would save a lot of money and eye problems when these diseases could be detected earlier.

Artificial intelligence is a promising technique that can help by detecting these asymptomatic eye diseases. It has the potential to make diagnosing these diseases easier and more affordable. However, tests in labs with AI systems seem to be promising but the introduction in the real world often fails.

According to research a well adopted medical tool should include a high prediction accuracy, be well adapted to the workflow of the clinicians, be easy to use for the target clinicians and explain why certain decisions are made.

To make sure the AI system will be adopted by the clinicians a service solution should be developed that make the service accurate, adapted to the different workflows, easy to use and able to explain its decisions clearly.

The service should be economically attractive for opticians

- Opticians are entrepreneurs, the service should be direct or indirect profitable for them
- The optician market is changing, profits are decreasing
- The service should be quick and easy to use for an optician and an optometrist
- 50-20% of patients still need mydriatic droplets with supervision of an optometrist

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- 50-20% of patients still need mydriatic droplets with supervision of an optometrist

The service should offer a place to discuss medical problems

- Empathy: Patients need time and attention for their problems
- Tradition: A new service should keep the good elements of the current service

The quality of the service should at least stay the same

- Morally, the service cannot create harm because of a preferred low false positive rate
- AI need to be used for diagnosing not for screening
- Ksyos strength: existing network of medical specialists
- Ksyos opportunity: focus on the whole service instead of just the algorithm
- Give clear info to GP, no interpretation required

The outcomes of the AI service should be adaptable to the circumstances

- Each caregroup will have their own requirements for the service
- The number of optometrists diverse per region
- GPs and ophthalmologists need some form of control over the outcomes

The service should communicate clear about potential unfairness

- The algorithm should not discriminate people with higher pigmentation rates
- When the false positive rate is high, the service should not provide a concrete advice

7.2 Design goals

Based on the take aways of the discover phase six main goals are devined for the final service.

The AI service should handle the detection of the three eye diseases differently

The next steps after detecting glaucoma are different then after detecting retinopathy. The AI system should handle these differences properly. Ophthalmologists already have long waiting lists, when the AI system sends to much unnecessary patients to them the support for the AI service will decrease.

The quality of the service should at least stay the same

The quality of the AI service is essential for the adaptation. The AI service should not be a screening service but a diagnosing service, this means that a GP should be able to count on the service that it will diagnose a patient correctly. To keep a high accuracy and the different medical specialists happy, the AI service should make use of the existing network of Ksyos. As mentioned before the ophthalmologist do not have space in their schedule for too much unnecessary patients. They want a low false positive rate, but a low false positive rate also means you will miss people that should have been referred to the ophthalmologist. To keep a qualitative service the solution should make good use of the existing network.

The service should be economically attractive for opticians

Most of the scans are now done at opticians, they play a crucial role in the current network. Providing the new AI service still needs to be economically attractive for opticians. This

could either be by delivering more customer service or getting enough money for the work they do.

The outcomes of the AI service should be adaptable to the circumstances

A care group responsible for the diabetic care in a certain region now has the opportunity to design the role of the different medical specialists based on the available specialists and costs. The to be developed AI service should also provide some kind of freedom to better fit into these different circumstances.

The service should offer the patient a place to discuss their problems with someone

An AI system alone could lead to a decrease of "empathy" in the service. Empathy however is important element for qualitative healthcare. The service around the AI system should provide besides an opportunity for patients to get in contact with a specialist in case they want to discuss their problems. Maybe the patient has another disease that needs to be checked by the optometrist.

The service should communicate clear about potential unfairness

People with more pigment in their skin also have more pigment in their retina. This could cause the AI system work less good for people who are not well represented in the training data. The AI service should communicate this clear to the medical specialists so they can make the right decision.



- Service design
- Service overview
- UX-design

8. The service

In this chapter we look at how the service could best fit the different requirements

8.1 Quality of diagnosis

Accuracy is the most important factor for the adoption of an AI system in the healthcare market. When a GP sends a patient to the new AI service, he needs to trust that the output of the system is accurate otherwise he will not use the service.

The current service of Ksyos ophthalmology is already different than the original way of eye screenings. In the past all patients with eye problems were referred to the ophthalmologist for a diagnosis. Right now, Ksyos makes use of their clever system of optometrists and ophthalmologists. The optometrists perform the eye screenings, and the ophthalmologists review the eye screenings to guarantee the quality of the service.

The AI system will not take over all the eye screenings from the optometrists. The system is able to detect clear true positives and clear false negatives but there are always diagnosis that are more difficult to predict. As discussed earlier the ophthalmologists have long waiting lists and do not want to have a lot of new patients who are unnecessarily sent to them. So, referring all the patient with a possible eye disease to the ophthalmologist is not an option.

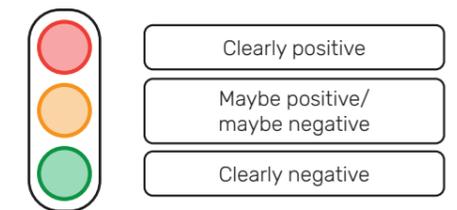


Figure 8.1. The division the algorithm makes in the three categories.

To guarantee a good service the AI system should divide the patients in people who need to be sent to the ophthalmologist immediately, people who are healthy and people who need further diagnosis to determine what the next step will be (Figure 8.1). This way the AI system will serve as a sort of gatekeeper. For the further diagnosis Ksyos can make use of their current network of specialists what gives the service also a competitive advantage over other companies that want to introduce an AI eye diagnosis system in the Netherlands.

8.2 Adaptability

Fundus eye screening programs are not organized nationally. Local groups of GPs called Ketens decide how they want to organize the screenings in their region. This is dependent partly on the availability of specialists. How many optometrists are there, is there a medical diagnostic center, are there capable opticians, how many ophthalmologists are available. Based on these specialists the Fundus eye screening is organized.

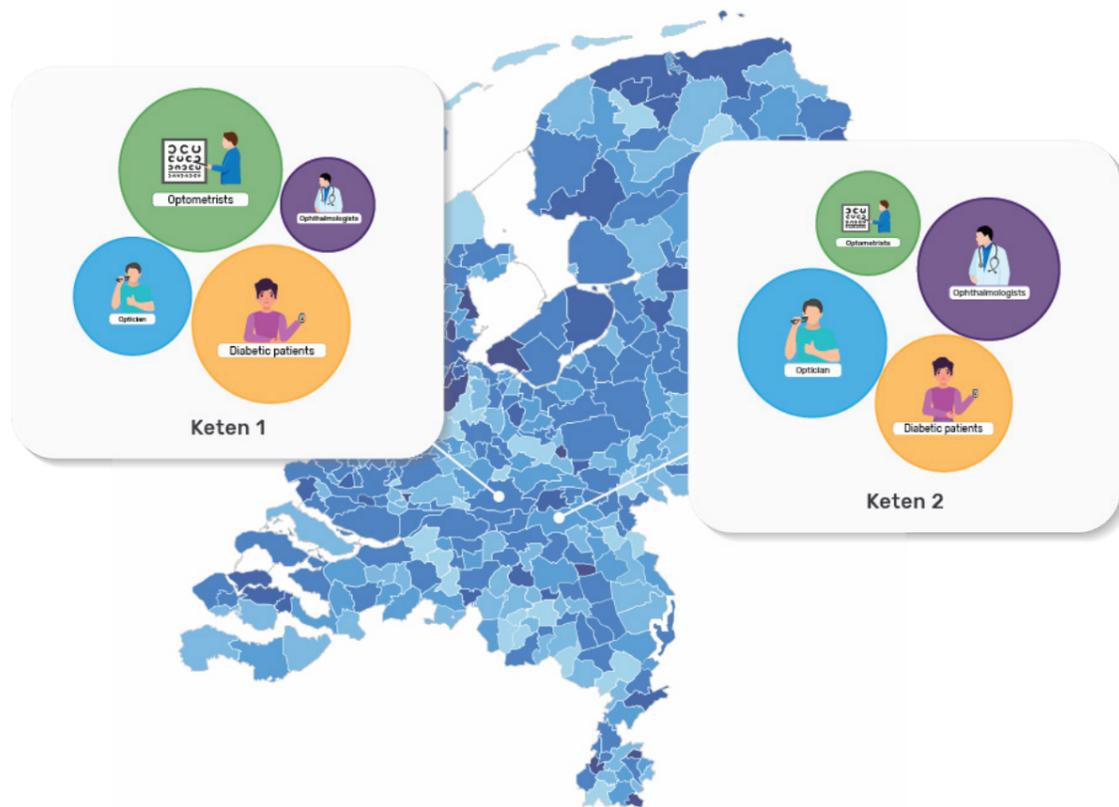


Figure 8.2. Each zorggroep has a different distribution of specialists and patients.

Another important factor for a successful implementation of an AI system in the healthcare sector is that it should fit in the workflow of the different specialists. The workflow in the fundus screening program is partly dependent on the availability of specialists in a certain area (figure 8.2). The

AI system should therefore be able to adapt to these different circumstances. This will give the different users some form of control over the AI system and make them able to adapt it better to their circumstances.

The goal of the algorithm is to diagnose people and refer them to different specialists. As discussed in the previous paragraph the patient will be sent to an ophthalmologist when the result is clearly positive and when there is doubt the person will get further investigated at an optometrist. The division of patients between these two groups is based on the algorithm. The way the algorithm divides the two groups can be made controllable.

First algorithm

There are different ways to build an algorithm that divides a group in three categories but according to healthplus.ai (the collaboration partner of Ksyos) in this case it is best to divide this task in two algorithms. The first algorithm will be responsible for detecting if the eye is healthy or not (See figure 8.3). When the eye is healthy this person falls in category green. When the eye is not healthy this person can be red or orange.

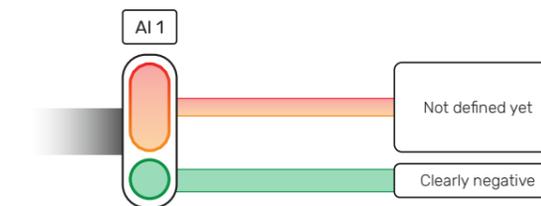


Figure 8.3. The first algorithm splits the group in healthy people and people who potentially have an eye diseases.

Second algorithm

The second algorithm will then determine the severity of the disease by putting people either in the red group or the orange group (see figure 8.4). The thresholds of this algorithm can be made adaptable. For example in one setup people with a probability of 96% or

higher of a severe case will be sent directly to the ophthalmologist and in another setup people with a probability of 92% or higher will be sent directly to the ophthalmologist. This way the algorithm will not be a one size fits all solution but a solution that matches more with the workflow of the medical specialists.

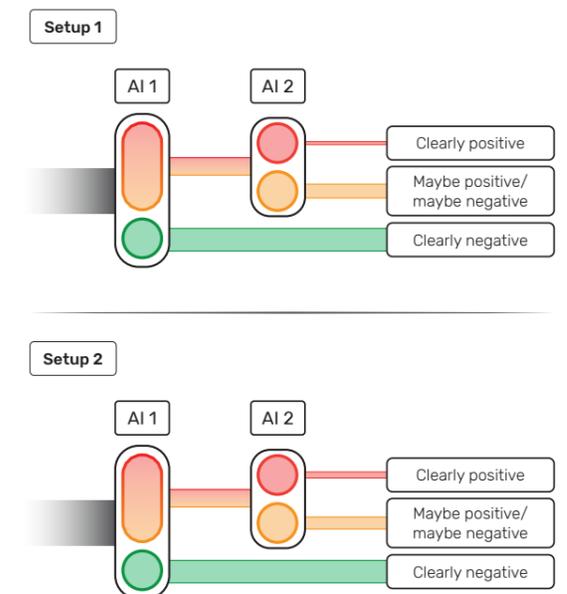


Figure 8.4. The second algorithm divides the patient who probably have an eye disease over the optometrists and ophthalmologist based on the setup of the algorithm.

Implementation

The way the algorithm is optimized should be based on a variety of factors like the available specialists, travel time and costs. This decision can best be made in the beginning stage of introducing the algorithm. Ksyos should decide this in collaboration with the representatives of the Keten they are working with.

8.3 Different diseases

While the fundus AI service can detect different eye diseases out of one fundus picture, the way the diseases should be handled is different from each other as discussed in the analyzing phase. In this paragraph we look at how the AI system should handle the different diseases.

Retinopathy

The goal of the AI system is not to detect retinopathy but to decide if the person need to be referred to an ophthalmologist or not. Red indicates this person need to be referred to an ophthalmologist. Green means this person does not have to be referred to an ophthalmologist, there is no or non-severe retinopathy spot in the retina. In this case the AI system should make a prediction of when the person needs to be scanned again, this is usually in 2 or 3 years. Orange means this person maybe need to be referred to an ophthalmologist. In this case the fundus pictures of the patient will be sent to an optometrist who will grade the picture and decide the next step (figure 8.5).

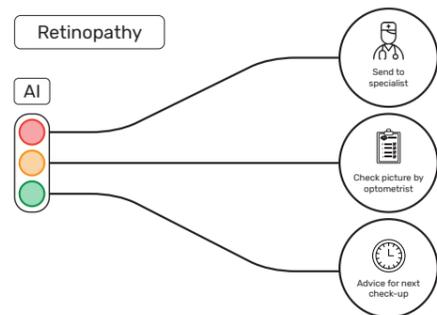


Figure 8.5. The different AI categories for retinopathy

Cataract

The effectivity of the treatment of cataract is not dependent on time. During the treatment the original lens is replaced by a plastic lent through surgery. When the AI system will discover cataract, the person should do a visus test to get a understanding about

their vision loss. Then they need to decide by themselves or in collaboration with their GP if they want the surgery (figure 8.6).

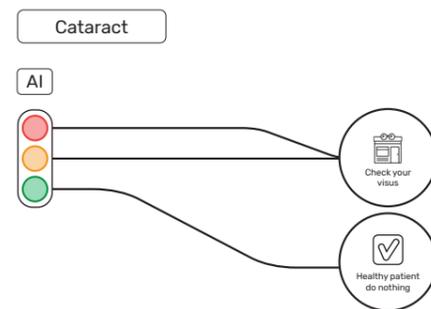


Figure 8.6. The different AI categories for cataract

Glaucoma

When glaucoma is diagnosed the patient should best be sent directly to the ophthalmologist. When there is possible glaucoma, the patient should go to a optician or an optometrist to measure the eye pressure and take an OCT. Based on these data in combination with the AI system the optometrist or ophthalmologist can decide if it is relevant to send this patient to the ophthalmologist (figure 8.7).

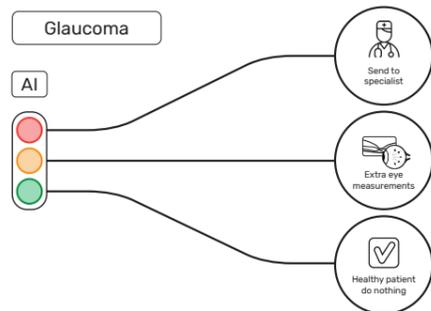


Figure 8.7. The different AI categories for glaucoma

8.4 Optician market

The current ksyos ophthalmology service heavily depends on optician stores, these are the ones who take the fundus pictures and grade them. Opticians are entrepreneurs and they are willing to provide these kinds of services if it is direct or indirectly profitable for them. But as in chapter ... mentioned the market is slowly shifting and the margins on glasses will shrink. It is important to design the service in a way that keep the service interesting for the people who should take the fundus pictures.

In the new service the fundus pictures can be taken by optometrists, opticians, GP assistants and employees of a pharmacy. They should all be able to run the AI software and explain the next step to the patient.

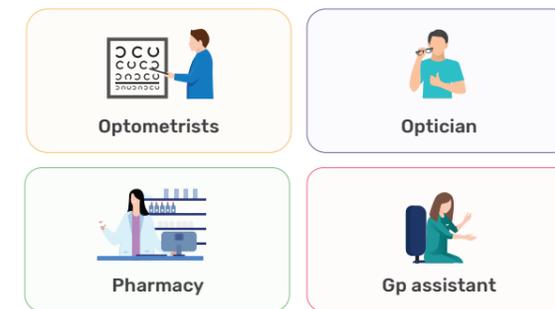


Figure 8.9. People who could take the fundus picture for the AI

8.4.1 The optometrists

The AI service will not improve the current workflow of the optometrist. The optometrist is skilled in detecting eye diseases and will spot diseases like cataract and retinopathy in an instant. Glaucoma however can sometimes still be difficult to spot for optometrists, an AI system could potentially help optometrists to become better in detecting glaucoma by for example people with a lower eye pressure. Optometrists could use this function to detect glaucoma, but then they have to change their workflow. As mentioned in the analysis optometrists use different computer programs during the eye screenings and Ksyos is often only used for documentation when the patient is already gone.

The role of the optometrist in the AI Ksyos ophthalmology service will change because of the AI system. More pre screenings will be performed by less educated employees. The AI system functions as a gatekeeper, patients with potential eye problems (orange on the traffic light) could be sent to the ophthalmologist. These screenings can be often categorized under the General Ophthalmology Examination and are more lucrative for the optometrists. It also could be more interesting for the optometrists their skills are better used and they potentially learn a lot.

The optometrist can also get the role of guarantying the quality of the service, this means they have to assess a percentage of the screenings of the AI system. This assessing of fundus pictures is an ideal task to earn money in quiet hours, for example Tuesday morning at 10 am when their will be probably no customers in the store.

While the margins on glasses will probably decrease the coming years there will still be a need for the more luxurious opticians. These opticians can still charge higher margins for better service. These opticians will still hire optometrists because these employees have more knowledge and are better able to help people. The human touch is important in these kinds of experiences. But as mentioned above these optometrists

could still work with Ksyos to make some more money in case there are no customers in the store, or their expertise is required for more challenging eye disease diagnosis.

-  Grading pictures in off peak hours
-  patients with more interesting problems
-  better service of glaucoma detection

8.4.2 The optician

The big optician chain stores, usually compete with each other on price. The introduction of online Visus tests could therefore be a threat. These online visus tests make it a lot easier for online stores, who do not have to hire opticians or a store, to sell glasses at a much lower price.

To compete with these online stores, opticians could choose to deliver a better eye service by measuring things that cannot be measured from home. The Ksyos AI service can help them to provide these kinds of services without having to hire expensive optometrists. The ecosystem of Ksyos can make these eye screening almost as good as at the optometrist. Only when the AI system communicates that there might be a problem (orange) sometimes an optometrist is needed to look at the data. This will do Ksyos for the optician but it will take a little bit longer for the patient to get the results.

-  Affordable way to provide a better service
-  Integration in healthcare network

8.4.2 GP assistant

The GP assistant is different from the other parties because it is not an entrepreneur. The other parties are willing to invest in systems to provide better service and potentially attract customers. The GP assistant does not have these motives. They are also not willing to pay the 20.000 euros for a fundus camera. When ksyos wants them to take the fundus pictures they should provide the camera.

The advantages of having a fundus camera in the GP building is that the GP can quickly scan a patient for potential eye diseases this way they can handle the problems of the patient quickly.

-  Quickly help patients at the practice

8.4.2 Pharmacies

Pharmacies are currently starting to sell glasses and perform visus tests as mentioned in chapter 3.7. They want to compete with the opticians by delivering the same glasses at a lower price. They could also start with performing AI fundus screenings to better compete with the opticians, but the structure of these stores could be a problem. Contact between customer and employee is different at a pharmacy than at an optician. At the optician customers can make an appointment and when a customer enters the store the optician has time for him. At the pharmacy this will be the case in quite hours, but at peak ours there is not someone who can help a customer for 15–30 minutes. A fully automated scanner could be the solution, these cameras are not available yet will likely be produced in the near future.

8.5 Fairness

For the AI system to be well adapted in the world the resistance towards a system needs to be limited. From an AI ethics perspective fairness could be the biggest problem. Treating people unfair based on skin color conflicts with the social norms in our society.

The pigmentation rate of the skin has a big influence on the color of the fundus picture. This means that the different diseases appear differently on the fundus picture. This would not be a problem if the training data set had enough examples of dark-skinned or albino fundus pictures, but this is likely not the case since the Dutch population consists of only 3–4 % dark-skinned people (CBS, 2021) and 0,006% is albino (Oogvereniging. (n.d.)). Figure 8.10 shows a guess of the pigmentation rate of the data set based on the CBS data.

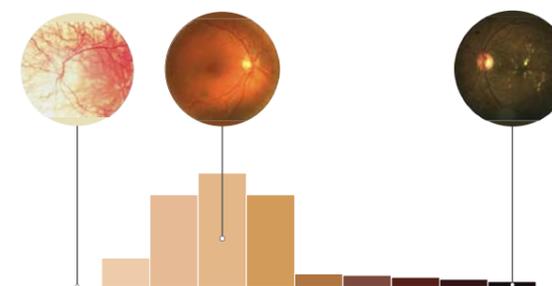


Figure 8.10, A visual representation of the predicted data set based on CBS data.

One way to prevent the problem of fairness is by manipulating the input data of the algorithm with filters, or by tweaking the input data of the algorithm. This is a proven technique that is able to compensate for differences in colors. If this is not effective another option will be to buy a data set with fundus pictures that are less representative in the current data set. This way the algorithm can better be trained to be able to help more people.

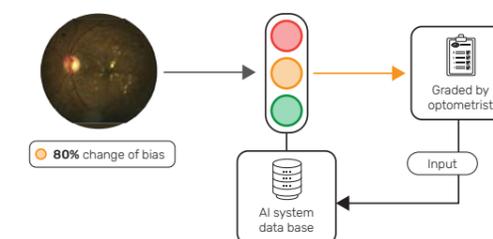


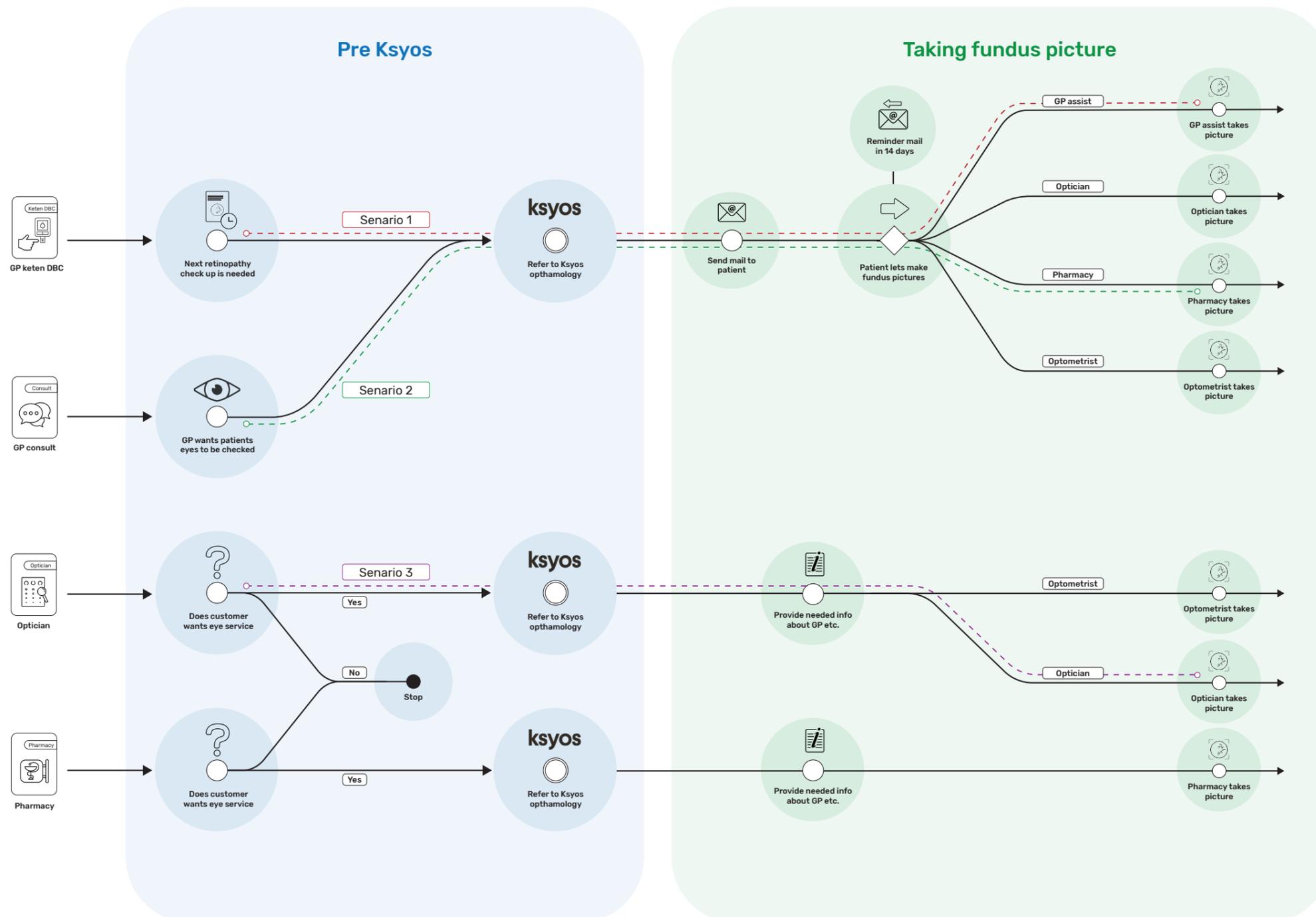
Figure 8.11, When the AI system cannot predict the picture because of a bias based on pigmentation, this person should go through the AI system to the optometrist this way data about these less common pigmentation rates will improve.

When the algorithm after tweaking is still not able to detect the different eye diseases for all people, the service should best be open about the bias of the system. It should encourage people to use the system that are not well presented in the training data set. This way the amount of data of their fundus pictures increase and the system will become fairer.

The system could show a bias score after the scan. This score could be based on the color of the fundus picture and data about the accuracy for these pictures. The exact way how to do this should be investigated when it is clear the algorithm cannot help everyone. When The algorithm thinks there is a change of a bias, the patient should be placed in the orange category. This means that there will be further diagnoses needed. The results of these diagnoses will be stored in the data set and used to improve the algorithm (Figure 8.11).

9. Service overview

In this chapter the different insights from chapter eight are combined into a service overview. The service will be presented and different scenarios are further explored.



9.1 The AI ophthalmology service

In this paragraph we walk through the service overview of the designed Ksyos ophthalmology AI service.

9.1.1 Taking fundus picture

The first stages of the service describe the paths patients can take to get their fundus pictures taken. There can be two main paths distinguished a medical path and a commercial path. In the medical path the GP uses the service to discover the patients potential eye problems. The commercial path is used by opticians and pharmacies to provide a better service.

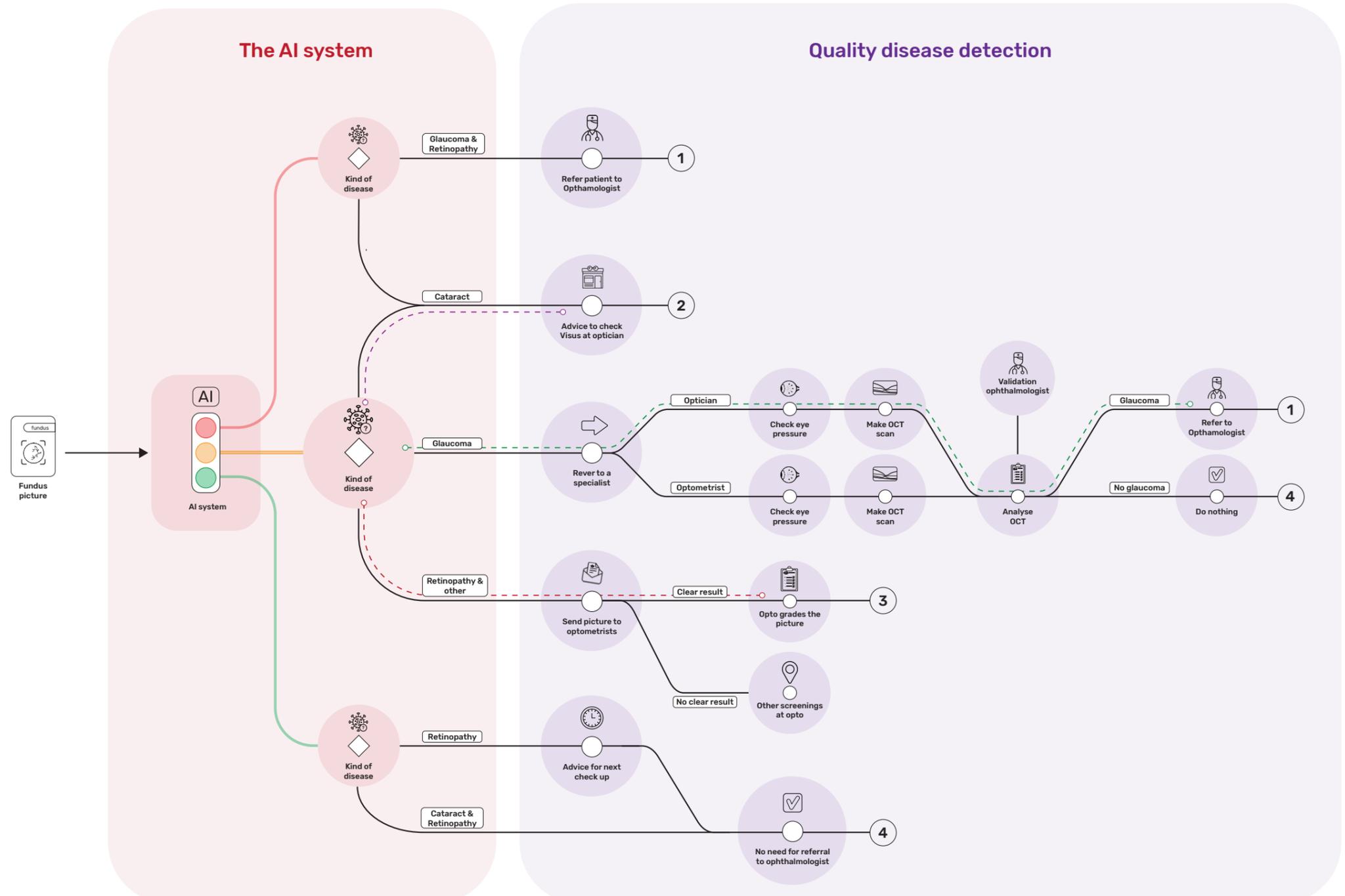
The medical path starts with a GP who wants the eyes of his patient to be checked. He refers the patient to Ksyos and Ksyos will send this patient a letter or a mail with a description of what is expected from them. In this mail will be a list of possible locations to scan your eyes. These locations could be GP assistants, opticians (with or without optometrists) or pharmacies. To help the patients one location could be marked as best choice based on location and costs for Ksyos. When the patient does not make an appointment in 14 days the patient will receive a reminder message.

The commercial path is a little bit different in this case the customer is already at the location the fundus picture can be taken. If the customer wants to have their eyes screened on diseases, then the customer first needs to provide some info like the name of the GP etc. for Ksyos. After that the

person working at this location can take the fundus picture this could be an employee of the pharmacy, an optician or an optometrist. When the picture is taken the picture will be uploaded to the AI server this server will look at the three different eye diseases earlier discussed: glaucoma, retinopathy and cataract. For each disease the AI system gives an indication about how likely it is this disease is developing in the eye. The system uses a traffic light to distribute the results between three categories. Red means there is a high change the eye disease is detected, green means there is a high change the eye disease is not present, and orange means the eye disease might be present. Based on this color and the kind of disease the next step will be determined.

8.6.2 Red

What happens after the AI system is different per disease. Red means for retinopathy and glaucoma that the patient should be referred directly to the ophthalmologist. When cataract is discovered, the patient can best first be sent to an optician. Time does not play an important role in cataract surgery; people only get surgery when they think it will be an improvement of their life. If they do not want surgery yet it is not useful to send them to the ophthalmologist. Sending them to an optician to do a visus test will help them to get a better picture about how bad their vision is in comparison to the average person. This could help them to make a better decision about if they want surgery or not.



8.6.3 Green

When the AI system shows the color green this means that the patient does not have to be sent to the ophthalmologist. For cataract and glaucoma this means the disease is not present in the eye, but for retinopathy the disease could still be present but not in a severe stage. The system therefore also indicates when the next retinopathy should be. When the disease is in a more severe stage the next checkup could be in 6 months. When the disease is not present the next checkup could be in 2 or 3 years.

8.6.4 Orange

Orange means that more diagnosing is needed to determine if the disease is present or not. For retinopathy this means that an optometrist or an ophthalmologist has to look at the fundus. The patient does not have to go to another location the picture can be sent through the Ksysos service to the right person to be graded.

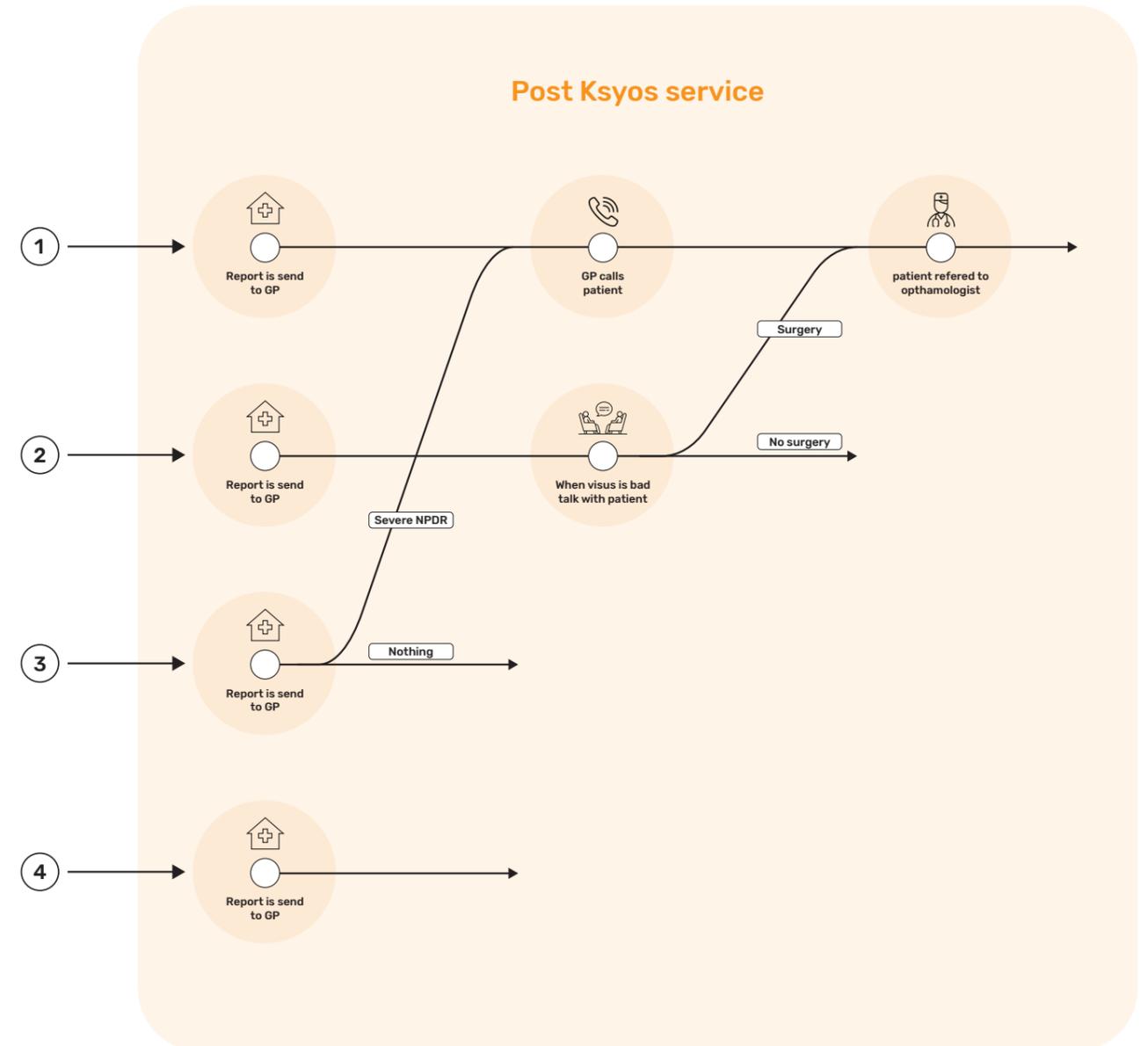
For glaucoma the advice by orange is the same as red. When the AI system thinks there might be glaucoma, the advice is to measure the visus.

When there might be glaucoma in the eye some other additional measurements should be taken. If there is no optician or optometrist present at the location the person is scanned, he needs to go to another location. An optician or an optometrist can measure the eye pressure and take an OCT. Based on these results a better prediction about the glaucoma can be made. The analysis of the eye pressure and the OCT can be done by optometrist with the validation of an ophthalmologist.

It is also possible that the AI system detects that the retina is not healthy but that the found characteristics do not match with one of the three diseases. In this case the picture will also be marked orange and sent to the optometrist. The optometrist will look at the picture and determine if it is necessary for this patient to visit the optometrist.

8.6.5 Post Ksysos service

The results of the AI scan will always be documented and send to the GP. The role of the GP is to discuss the results if necessary. When the advice is to send the patient to the ophthalmologist the GP will discuss this result with the patient and refer the patient to a nearby ophthalmologist. When the patient did a Visus scan, and his vision is bad the GP could discuss the possibility of surgery with the patient. The results of the retinopathy scan can be discussed at the next diabetic checkup.



9.2 Scenario's

In this paragraph we look a bit deeper into the service based on three scenarios. Each person walks through the service in a different way. They all have different starting points use the system to discover different diseases and interact with different people but use the same AI service.

8.7.1 Scenario 1: Retinopathy screening

This scenario is about a diabetic person he needs to check his eyes every 2-3 years on retinopathy. His GP practice uses Ksyos new AI service to perform those screens.

1. receiving a letter

He receives a letter from Ksyos, the letter tells him that it is time for a new fundus screening; it has been 2 years ago since the last screening. The letter also tells him that Ksyos is now works with an AI system and that screenings can be done at more locations even at the GP practice.

2. GP practice

He decides to go to the GP practice since this is the nearest to his home. He makes an appointment and goes to the practice.

3. Taking the picture

The GP assistant has a fundus camera, and she makes two pictures of each eye one from up front and one from nasal. The pictures have atomically been stored on the computer through the camera software.

4. The algorithm

The GP assistant uploads the pictures to the Ksyos AI server and receives the results. The results show that their might be retinopathy

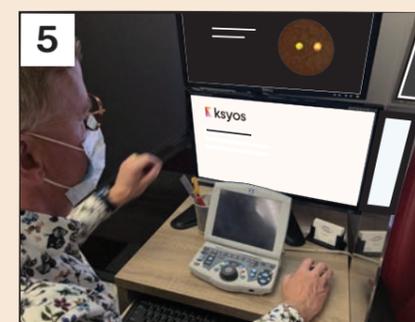
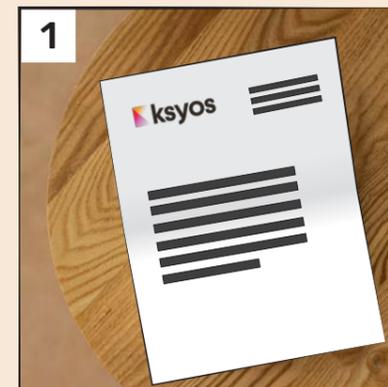
but the system also shows that this can be caused because of the bias of the system. The GP assistant decides in collaboration with the patient to send the pictures to an optometrist to check on retinopathy. The patient is also explained that his data can be used to better train the algorithm and reduce the bias of the system.

5. The optometrist

An optometrist who works at an optician receives the data from the GP assistant. He looks through the pictures and sees no retinopathy. He grades the pictures and send the results back to the GP.

6. The result

The GP receives the results from the optometrist. He calls the patient and explains that there is no retinopathy developing in his eyes. He says that it could have been caused by the bias of the system but that his provided data will improve the system in the future.



8.7.2 Scenario 2: Glaucoma screening

This scenario is about an older person who has often a red eye and headaches he goes to the GP for help. *(this is the most complex path based on disease and locations and parties involved in the process.)*

1. GP consult

He goes to the GP to explain his problems. The GP thinks based on the symptoms in combination with the age of the patient and the fact that his father had glaucoma in the past, that it is best to check on glaucoma. He refers the patient to Ksyos.

2. Letter Ksyos

The patient receives a letter from Ksyos that provides him with a list of locations to do the fundus screening

3. Drugstore

He already needed to go to the drugstore, so he decides to do the fundus screening there. He is not approached immediately when he entered the store and needs to find a person who could help him.

4. Taking the picture

The employee from the drugstore first needs some information about him to put in the Ksyos system then she takes four fundus pictures

5. AI result

The employee uploads the pictures to the AI server, the result shows that there might be glaucoma in the eyes. There needs to be more diagnosis, but this is not possible at the pharmacy. She refers him to an optician.

6. optician

He makes a new appointment with an optician and goes to the optician

7 + 8. Additional measurements

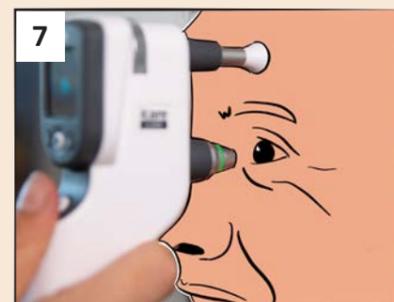
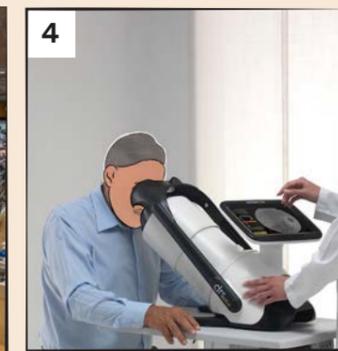
The optician measures the eye pressure, a high eye pressure could be an indication of glaucoma. And he takes an OCT scan this gives a better view of the deeper layers of the retina. The optician is not trained to interpret this data, so he sends it to an optometrist.

9. Optometrist

The optometrists receive the fundus picture, the eye pressure and the OCT. Based on this data he decides if the person has glaucoma or not. His report will first be sent to an ophthalmologist who validates the findings of the optometrist. When the ophthalmologist agrees the result will be sent to the GP.

10. the result

The GP receives the results from the optometrist. He calls the patient to discuss the next step. The patient has most likely glaucoma and he will be referred to an ophthalmologist.



8.7.3 Scenario 3: Cataract screening

This scenario does not start at the GP but at the optician. The customer is going to buy a new set of glasses and need her eyes to be measured again.

1. Picking glasses

The customer enters the store and looks through the glasses. The optician asks if he could help her. She says that she wants these glasses. He asked when the last time was that her eyes were measured. She replies that her vision is worse than before and that she wants to measure her eyes again.

2. Eye measurements

The eyes of the customer are measured but the vision is a lot worse than expected. The optician explains that this could be cataract. They have a new AI tool that can detect cataract. The customer wants to know what is wrong with her eyes and agrees to use the AI system.

3. registration Ksyos

The customer needs to provide some information to Ksyos like the name of her GP.

4. Taking the picture

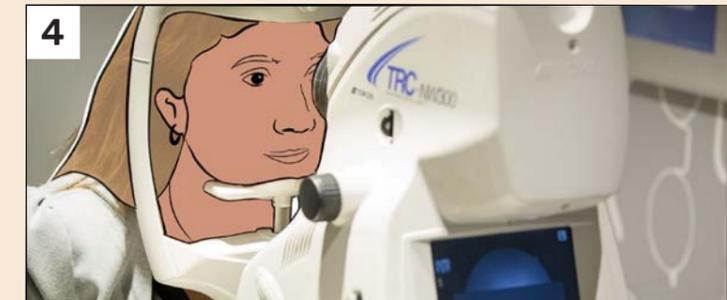
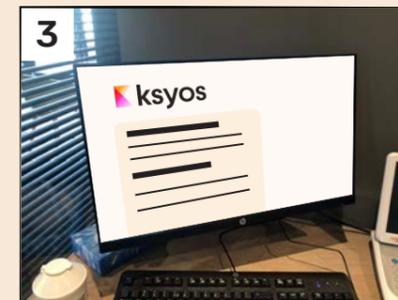
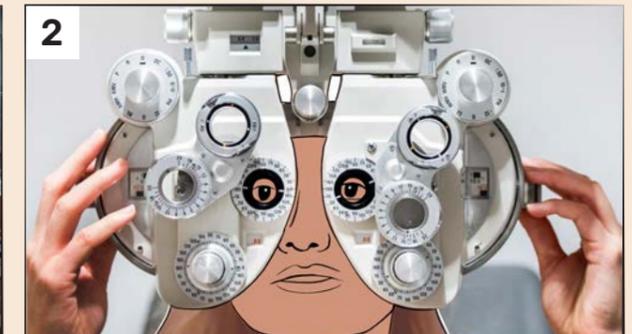
The optician takes the necessary four fundus pictures, two of each eye.

5. the results

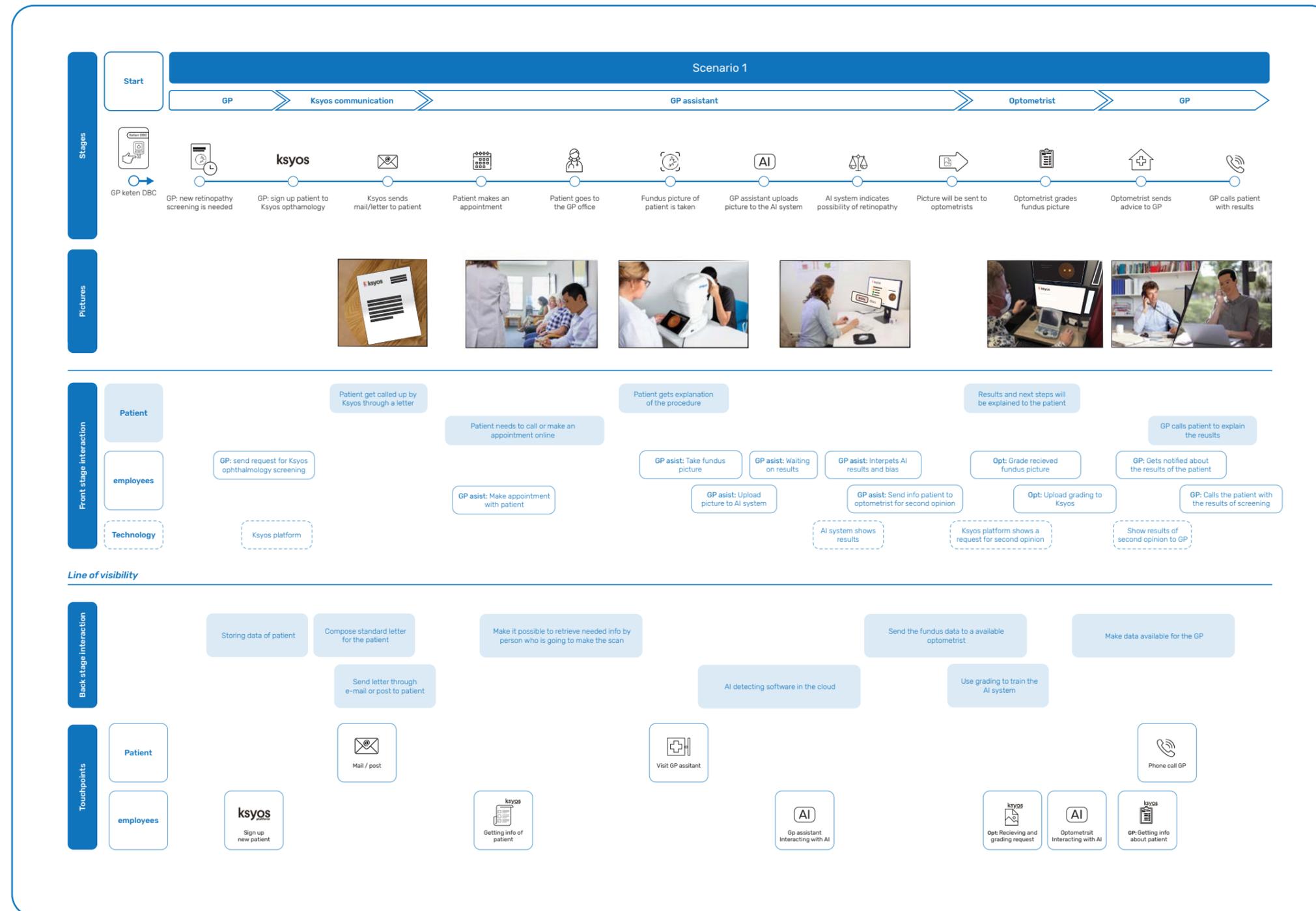
The optician uploads the picture to the Ksyos server. The AI system indicates that this is cataract. The optician explains a little bit what can be done to treat it and tells that the info will also be sent to the GP.

6. The GP

The GP calls the patient and discusses the vision loss and the possibility of surgery to treat it.



9.3 Service blueprint

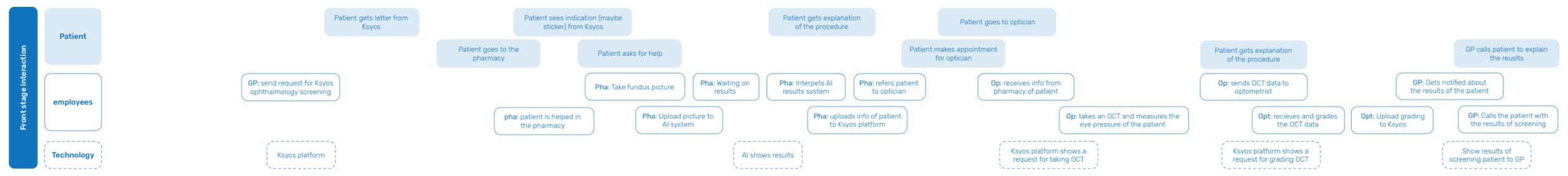
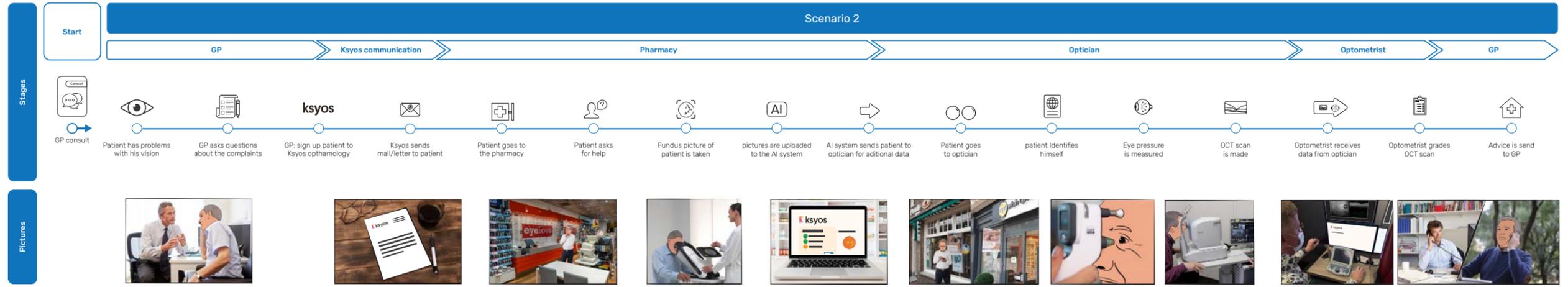


In this paragraph we use a service blueprint to visualize the service process and break it down into components that need to be designed.

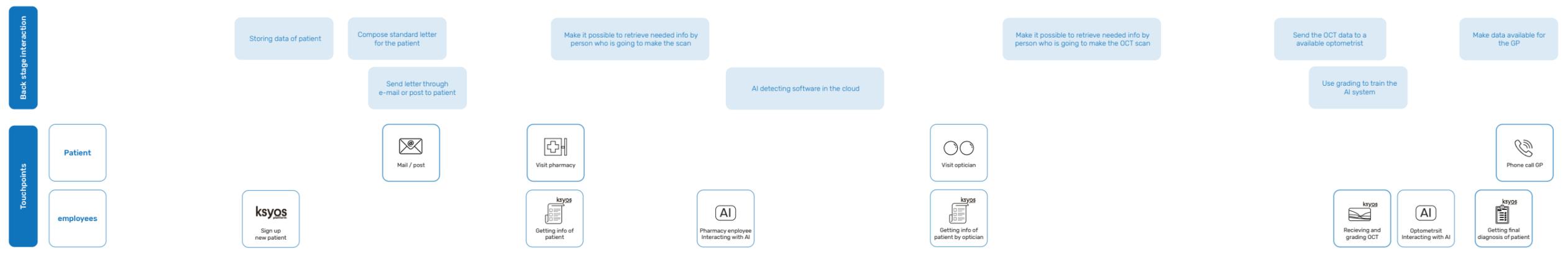
8.6.1 Service blueprint

A service blueprint is a tool that helps to get a deeper understanding of the different actions required to deliver a service. It splits the required actions in two types: the front stage actions and the backstage actions. The front stage actions are the actions visible for the user of the system and the backstage actions are the required actions that are not visible for the user. To get a good overview of the particular actions needed during the use of the AI eye disease detection service, all three scenarios are transformed into service blueprints.

Scenario 2



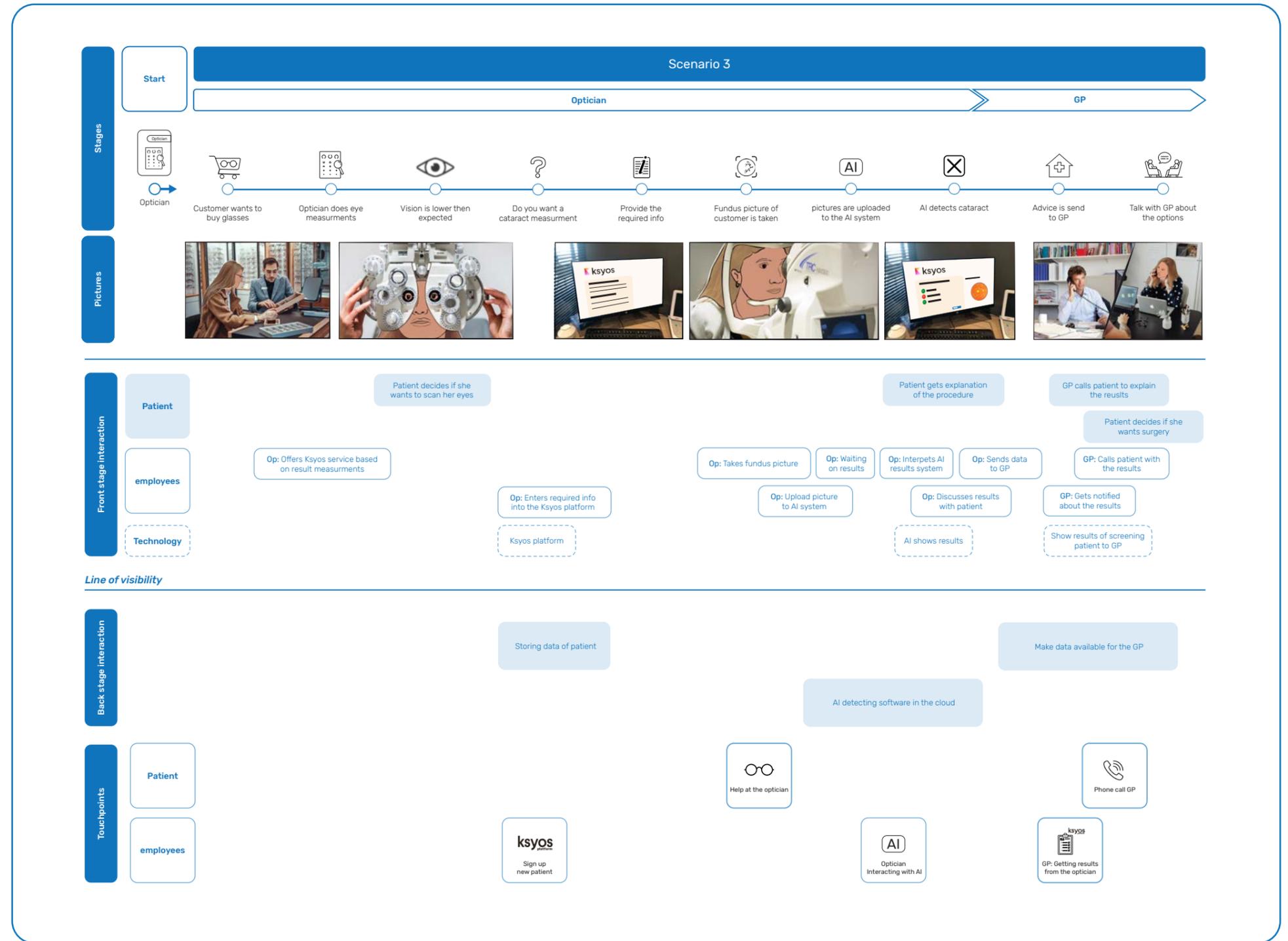
Line of visibility



8.6.2 Important touchpoints

Most of the actions required for delivering the service are already in place because they are also present in the current Ksyos ophthalmology service. For example, the backstage task of creating a letter and letting people know that they need to take a fundus picture. This letter maybe needs to be changed a little bit, but the overall backstage action stays the same.

The most changes will take place around the interaction with the AI system, these are the touchpoints of opticians/GP assistants/ pharmacy employee interacting with the AI system and optometrists/ophthalmologists interacting with the AI system. These two are the most interesting touchpoints to look deeper into how they need to be designed.



10. User experience

In this chapter we look deeper at the user experience of the chosen touchpoints that need further investigation.

10.1 Workflow

For the user experience the way the AI system fits in the workflow is important. This is especially important in the medical sector, the workflow plays a crucial role in whether or not a new technology is adopted. In this paragraph we look at how the AI system should best be fitted in the current workflow.

10.1.1 Taks

As discussed earlier in the service overview, the optician will take over the task of taking fundus pictures and scanning them on potential eye diseases from the optometrist. While the task itself is not that much different the workflow will be.

In the current workflow the optometrist first takes the fundus picture of the patient. Then he will grade the pictures immediately on the monitor of the fundus camera. Grading a fundus picture takes about 15 – 30 seconds for an optometrist. He will then discuss what he found with the patient usually this does not take place in the store but at a more private room backstage. After the explanation the patient goes home, and the optometrist fills in the required data in the Ksyos portal and uploads the taken fundus picture to the server (Figure 10.1).



Figure 10.1, Current workflow of the optometrist.

The optician however cannot see in an instant if an eye disease is developing or not, he will use the AI system. The optician will also first take the fundus picture, then he will upload this picture to the Ksyos AI system in the cloud. The AI system will analyze the pictures and send the results back to the optician. He will discuss what has been found with the patient and upload the data to the server (Figure 10.2).

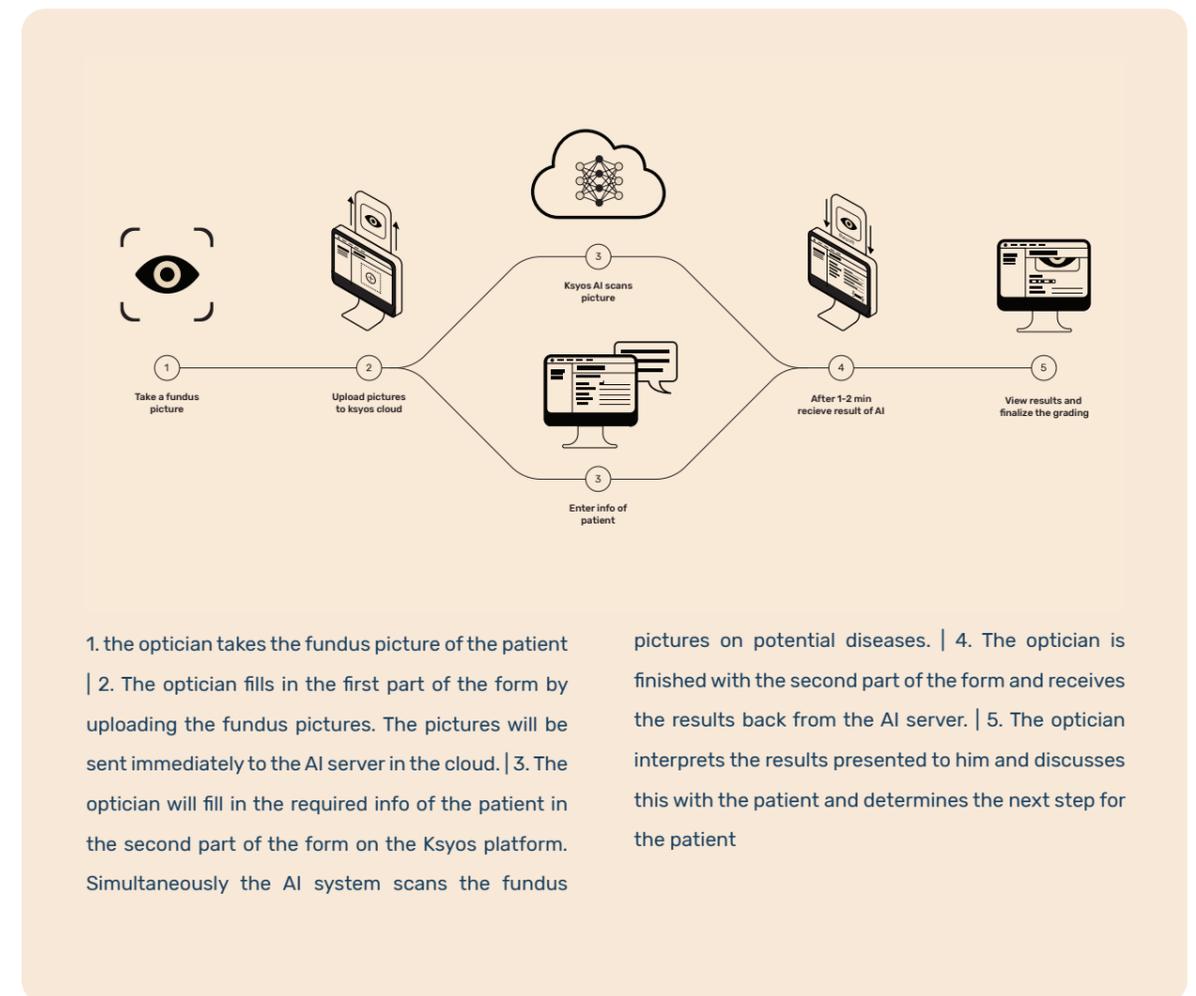


Figure 10.2, Potential new workflow for the optician.

8.7.2 Time

Time is a critical factor in the workflow, when the process is not one integrated experience the adoption rate of this new technology will drop as mentioned in Appendix A4. The AI system will take about 1 – 2 minutes to analyze the eyes on potential diseases. This waiting time would interrupt the whole experience of the AI system.

It is best to split the current ophthalmology form into two parts. The first part will only require the optician to upload the fundus pictures. The second part will ask to fill in the other required data. While filling in the second part the AI system can start with scanning the uploaded pictures. This way the waiting time will be reduced or taken to zero.



10.2 Prototype

To be able to test the intended workflow with the optometrists and get qualitative feedback a prototype was made. The goal of this prototype will be to give the optometrists a visual experience of what it will be like to use the AI service, it will be used to start a conversation about how it best can be fitted in their current workflow.

Creation

Because I wanted to give the user a feeling about what it is like to use the AI service an interactive prototype was made. This way the time people need to wait for the algorithm to finish can best be experienced. The prototype was made by creating an application for the iPad using XCode (figure 10.3).

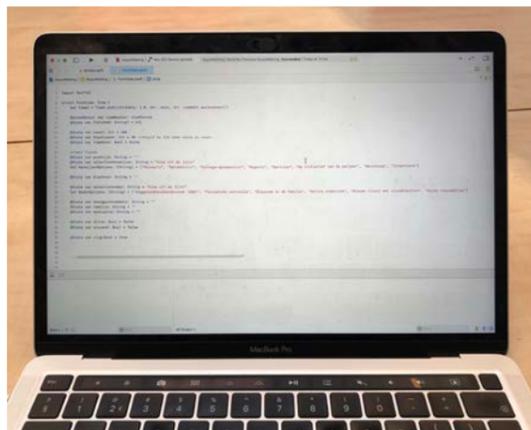


Figure 10.3. Programming the prototype

The design of the interface is based on the current interface of the Ksyos platform (figure 10.4). This interface has a big bar with information about the current patient on the left side. And on the right side, it has an active interactive part where the optometrist can enter the needed info. I

did not change that much to this interface because I wanted the test to be focused on the time the AI system takes to screen the pictures.

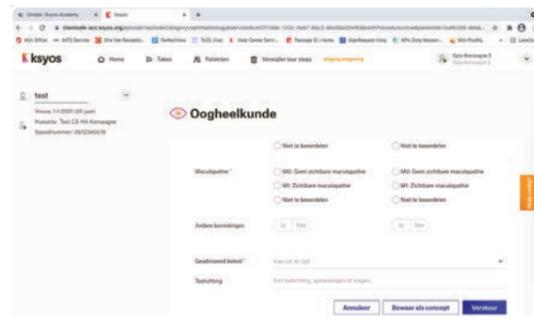


Figure 10.4. An impression of how the current Ksyos ophthalmology site looks like

Screens

The application consists of three screens, the first screen is for uploading the pictures, the second screen is to add additional info to the form and the last screen will show the results of the AI system.

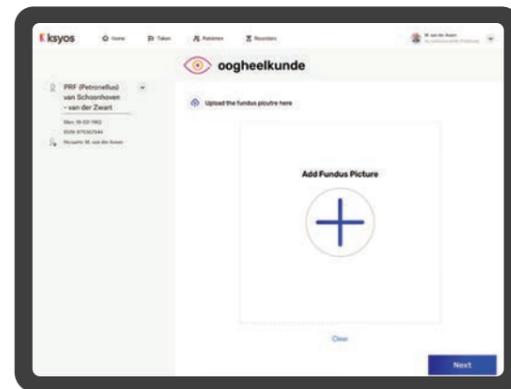


Figure 10.5. the first screen of the prototype.

1. Upload screen

The first screen is only used for uploading the fundus picture (figure 10.5). The user

can press the blue plus button and chose one of the three preloaded fundus pictures. After choosing the fundus picture he can press next to go to the next screen.

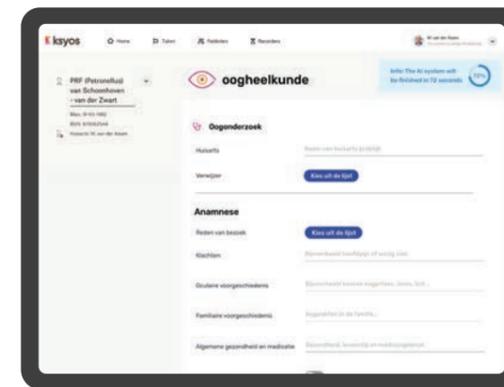


Figure 10.6. the second screen of the prototype.

2. Screen with form

On the second screen a timer will start ticking on the top right part of the screen, this timer simulates the time it will take for the AI system to scan the pictures. The user cannot go to the next screen until the timer is finished. While the user is on this page, he can add the needed additional info of the patient (figure 10.6).

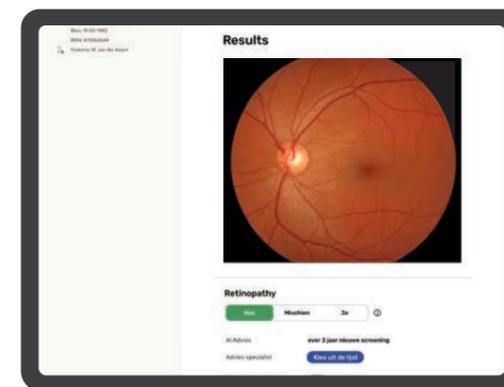
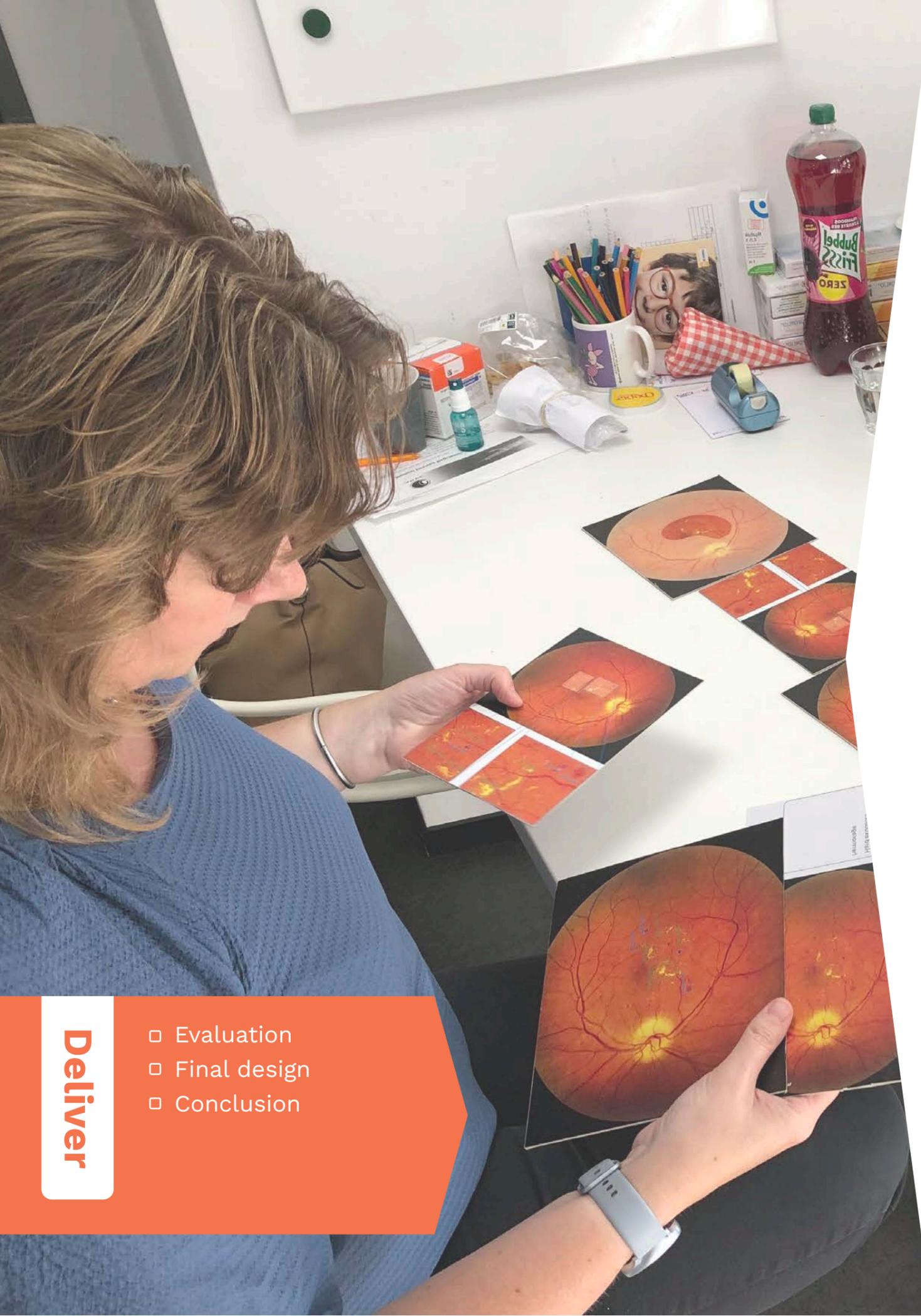


Figure 10.7. the third screen of the prototype. .

3. Results of the AI system

The third screen shows the results of the AI system. The user can see the advice of the AI system and the severity of the disease. Based on this information the user can enter their advice for this patient. When the full form is filled in the user can press sent to send out the form (figure 10.7).

A full overview of the different screens of the prototype can be found in appendix A5.



Deliver

- Evaluation
- Final design
- Conclusion

11. Evaluation

In this chapter we at the evaluation of the designed service we will first look at the service design itself, then we look at the evaluation of the workflow and at the end at the evaluation of the communication with the algorithm

11.1 Service design

The first test focusses on evaluating the designed AI service. The goal is to check if the way the AI system is implemented in the service will improve the current ophthalmology service and if the different decisions made during the design of the service are matching the reality.

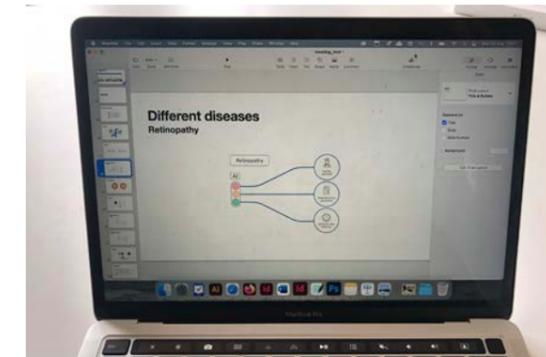


Figure 11.1, Presentation slide for the optometrists

11.1.1 Method

For this evaluation 3 optometrists were interviewed. The method used to evaluate the concept is a concept walkthrough, the goal of this method is to walk the intended user or expert through the intended service and ask for feedback. The full AI service is first explained using the service overview. Then the deeper decisions made during the design are further discussed using different drawn

scenarios and visuals. While discussing the service the optometrists gave feedback and comments on the presented work.

11.1.2 Results

The overall service is seen as valuable by the optometrists, the way the algorithm is used means that it takes a lot of unnecessary patients away from the optometrist so they can better help the people who really need their expertise. It also has the potential to scan bigger populations. The decisions made for every disease are overall good, but there were some remarks that need to be taken in consideration.

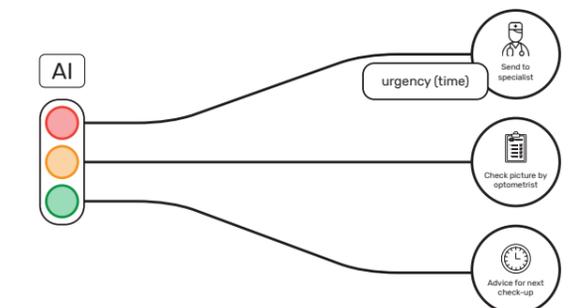
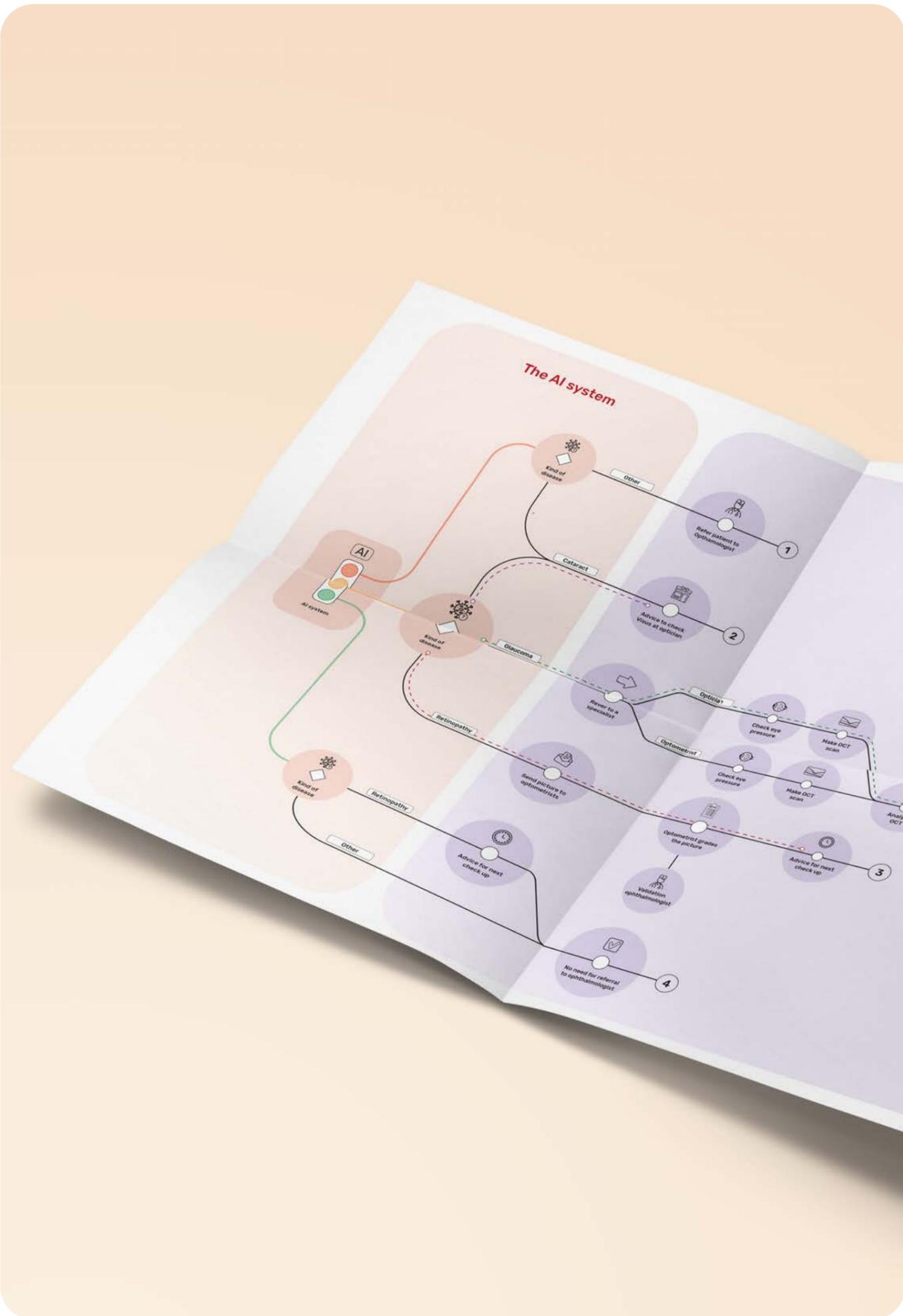


Figure 11.2, Improved retinopathy screening, by adding the urgency for visiting the ophthalmologist.

Retinopathy

For retinopathy the stages are quite clear which means the algorithm would work well. The only thing that is missing in the current



concept is the timeframe in which someone should be sent to the ophthalmologist. This timeframe diverse a lot based on the severity of the disease. One person maybe needs to be sent immediately to the ophthalmologist and another person can easily wait for three months. This data is already included in the current Ksyos form and therefore also available in the data set. This means that this can be implemented into the AI system (figure 11.2).

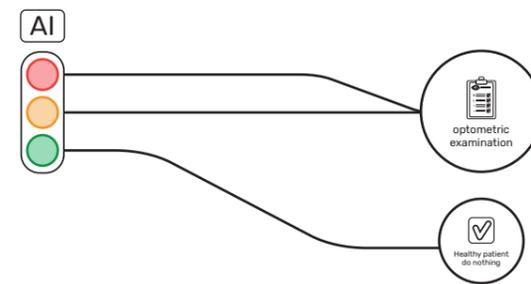


Figure 11.3, Improved cataract screening, by replacing the visus scan with an optometric examination.

Cataract

When cataract is discovered in the fundus picture, it is based on the difficulty you can see through the lens. If you cannot see good through the lens you cannot say anything about retinopathy, glaucoma, or other diseases.

Because cataract often appears in combination with other diseases like retinopathy or glaucoma it is recommended to send people with a probability of cataract to the optometrist for further research (figure 11.3). The optometrist can also help with a better determination about if someone needs surgery. To determine if someone with cataract needs surgery a visus scan plays

an important role but there are more factors that need to be taken in consideration. For example, how important a good vision is for his job and others safety. A bus driver needs earlier surgery then someone that has a job where a good vision is not crucial.

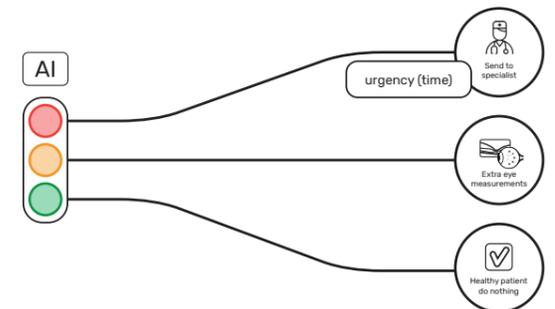


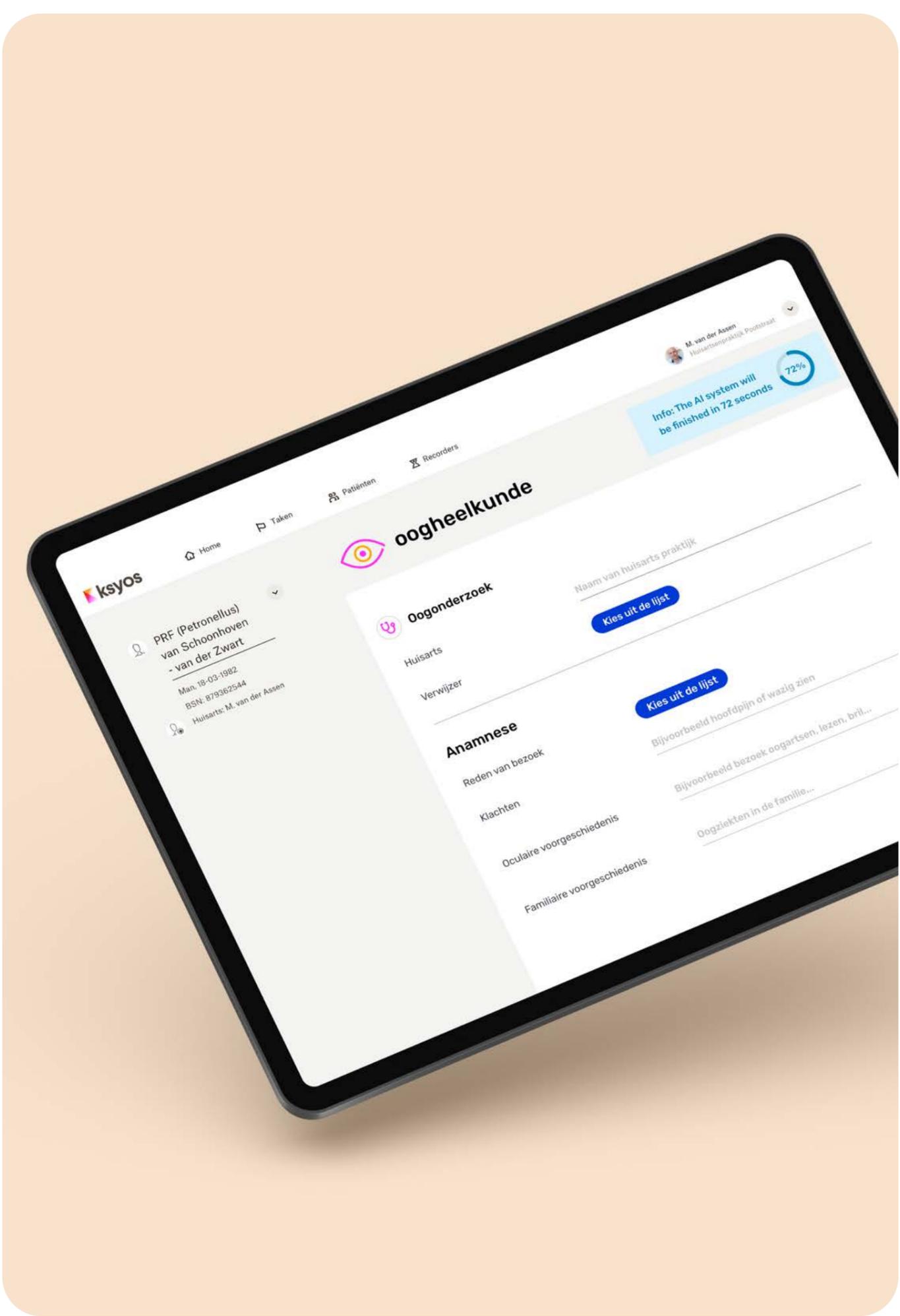
Figure 11.4, Improved glaucoma screening, by adding the urgency for visiting the ophthalmologist.

Glaucoma

The current way of handling glaucoma in the AI service is good, but just like retinopathy the timeframe in which someone needs to be sent to the ophthalmologist is important and should be included (figure 11.4).

Fairness

The fact that the AI system could potentially still sent people with a higher pigmentation rate to them is fine. These kinds of pictures are more difficult to grade because the differences are more subtle and sometimes not visible in the picture. The optometrists often do not use a fundus camera but an ophthalmoscope to detect the diseases. An ophthalmoscope makes it easier to view the fundus from different sides and with the use of extra lightning the diseases are detectable.



11.2 Workflow evaluation

As mentioned before the effect on the workflow is an important factor for the adoption of new technology in the healthcare market. With this seconde test I looked at how to make the implementation in the workflow as smooth as possible

11.2.2. Results

The idea to separate the form into two parts as discussed before was appreciated. By uploading the pictures at the beginning of the workflow to start the AI scanning can save some time, and when the task needs to be performed frequently it can save up a lot of time.

The form itself on the second tab had some unnecessary elements according to the optometrists, for example some questions are only relevant when there will be a full ophthalmology examination and not when there is only a diabetic retinopathy checkup. Information that can be added to the form are the visus scan and data about family history of glaucoma, this data is now asked in a text field but a toggle can be easier to use in the AI system.

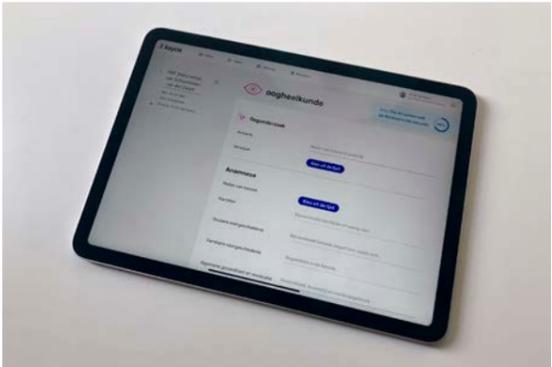


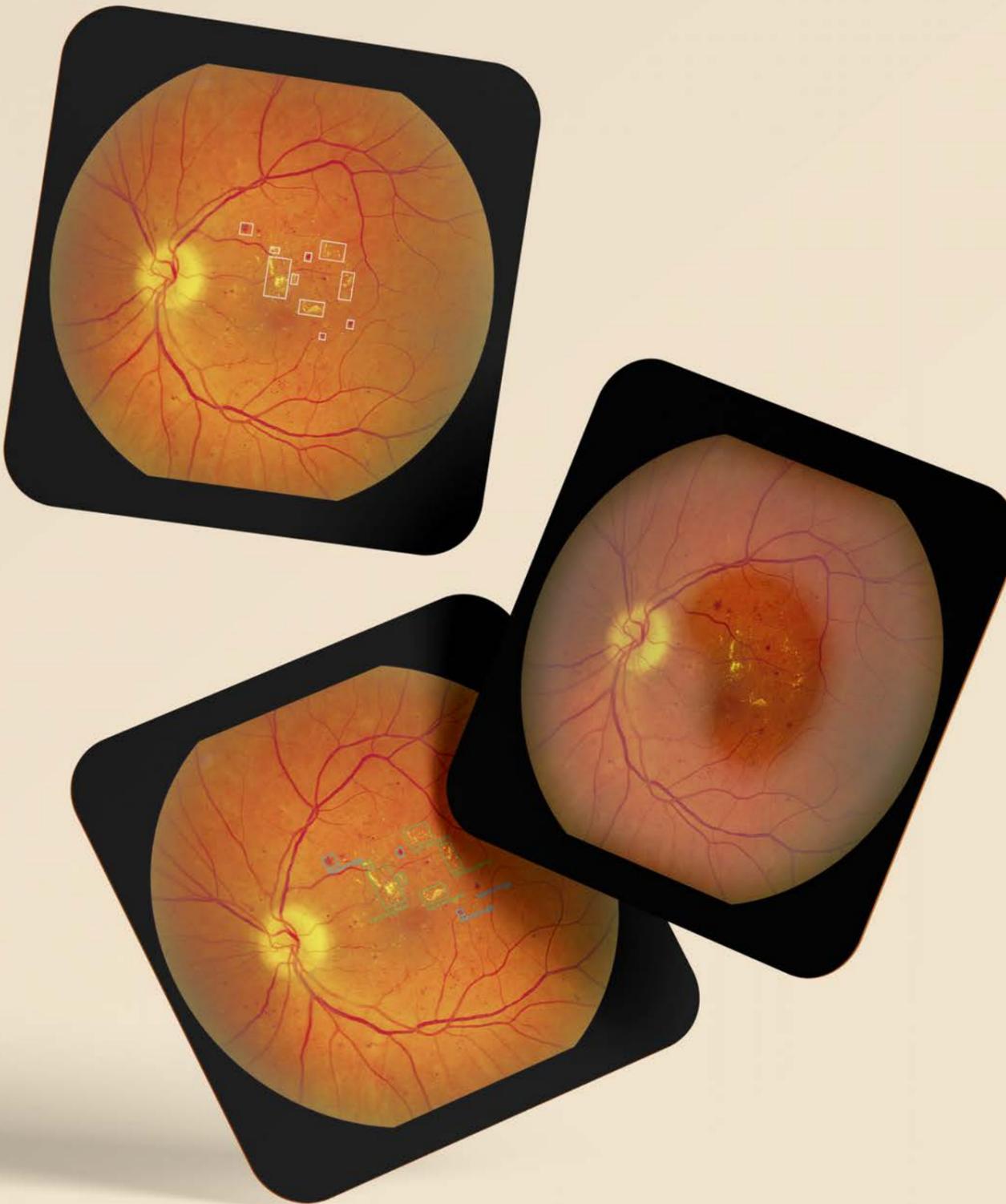
Figure 11.5, Picture of the prototype used during this test

11.2.1 Method

The goal of this evaluation is to find out how the optometrists views the implementation of the new service in their workflow and the workflow of the opticians. For this evaluation again 3 optometrists were interviewed. The method used to evaluate the workflow was an experience prototype. The goal of this prototype is to give the user a feeling about what it is like to use AI server. This way the user better understand how it could or could not fit in their workflow. To create the experience prototype an app was created for the iPad (figure 11.5). The app simulates the way the service is intended to look like. While using the prototype the participant is asked to give their opinion and view on if and how the implementation can be improved.

Communication with patient

It is maybe not best to let the optician interpret the results of the AI system and discuss this with the patient. The optician needs of course feedback from the system to let them know what the AI system does but according to optometrists the optician has too little knowledge about this subject to explain this properly to a patient. When there is something wrong with someone's eye, they usually want answers immediately. When they leave with too many questions or in panic, they will call the GP and demand an appointment with an ophthalmologist. This is something the GP and the ophthalmologist do not want. The information can best be presented through the doctor or through a clear letter. The letter should explain clear and calm what the next steps in such a procedure will be.



11.3 UX-design

For the AI system to be adopted well the results should be explained in a clear way to the targeted clinicians. The goal of this third test is to get a better understanding of what the AI system in which way should communicate to the optician and the optometrist.



Figure 11.6. Three subgroups of the AI output; visual, gradation and advice.

11.3.1 Method

The output of the AI system will be split in three subgroups the visual output, the gradation output, and the AI advice. The visual output is about how the AI system can visually communicate what it found. The gradation output looks at how the AI

system should communicate to which category they think the picture belongs. And the Advice looks at what information the AI system should provide to the end user, so he knows what to do. The separation of the three subcategories is shown in figure 11.6.

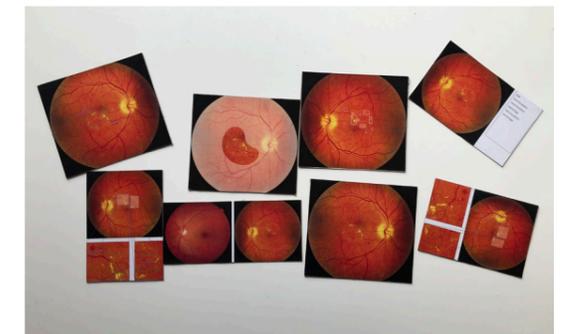


Figure 11.7. A sample of the cards used during the test.

For each of these categories multiple ideas are developed and created. Figure 11.7 shows the different ideas for the visual representation (a full overview can be found in appendix A 6-8). Because the difference between the ideas are very subtle, the participants are asked to put the different ideas in order from best to worst based on a statement (figure 11.8). This forces the participants to make a decision. During the test the participants are also frequently asked to explain why they make these decisions.

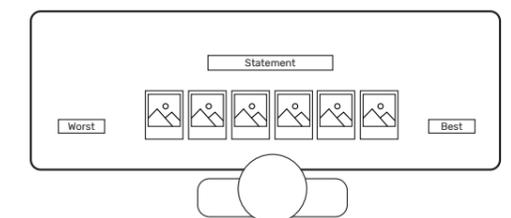


Figure 11.8. The setup for the Test.

Results opticians

Statement 1: The first statement is focused on the optician. An optician has made a picture of a patient and runs it through the AI system what kind of information does he need to trust the AI system. The results are based of 5 respondents

Visual communication

For the visual communication the optician wants a clear simple way of communication. The optician does not have the knowledge about difficult medical terms. They do not need this information and are also not able or allowed to interpret this information.

There were two ideas the opticians liked the first one showed a healthy eye next to the just photographed eye, this helped them to see that there was indeed something developing in the eye that was not normal. And gave them a good reason to send these people to an optometrist (Figure 11.9).

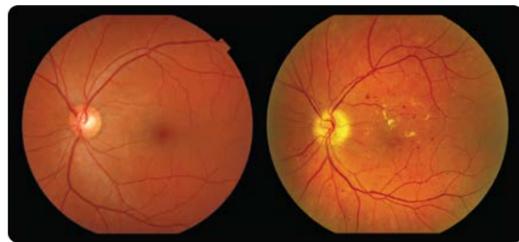


Figure 11.9, Comparison between normal and current picture

The second one the opticians liked was a fundus picture with white boxes around the parts the AI system thinks are not normal. While the colors or the shapes inside these white boxes do not mean anything to the opticians, they can see that these things are not normal what helps to convince them that

the AI system does have found something unhealthy in the eye (Figure 11.10).

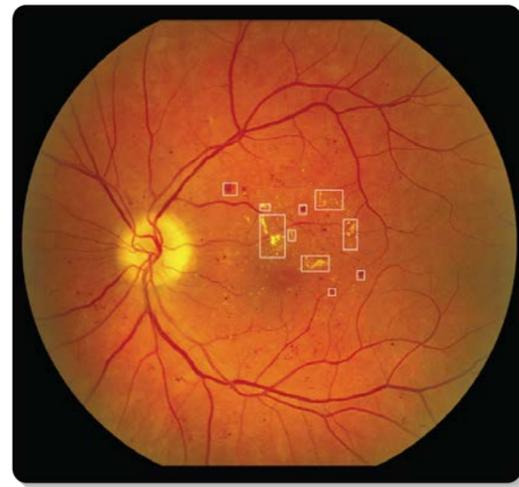


Figure 11.10, Picture with white boxes around unhealthy parts

Gradation communication

For this test the opinions were more separated and for a good conclusion the test should be performed by more opticians. But what I learned from the conversations is that the use of color in this segment is important it communicates clearly without having to read. When you perform the same tasks regularly this really helps. The idea most participants liked is the one that shows the three categories with a color indication for the communicated category. It gives a good overview of the options and clearly show the result (figure 11.11).

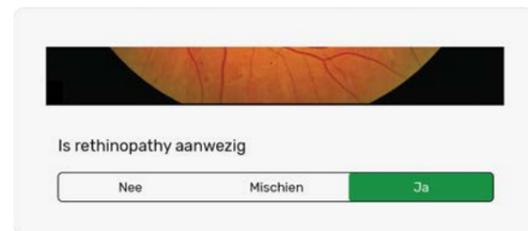


Figure 11.11, Clear separation between the different options

AI advice

Most of the opticians did not like the ideas that showed an advice based on more complex methodology. They mostly indicated that they preferred a short explanation. If there was a longer explanation, they wanted this explanation to be only visible when needed, for example under an info button. But the role of this explanation should not be to explain the whole disease but more about what the next steps should be. It should not be an alarming message.

Results optometrist

Statement 2: The second statement is focused on the optometrist. The AI system makes a decision, but the optometrist does not understand why the AI system makes this decision. How does the optometrist want the AI system to communicate what he thinks he sees?



Figure 11.12, Optometrist performing the Test.

Visual communication

The optometrists indicate that there are two things important. The first one is the location of what is found and the second one is what the AI system thinks this specific part is. There are two ideas that provide this kind of information. With

boxes are the locations indicated and text explains what the AI systems thinks it found. The Idea that allows to zoom in on a specific part because this gives them even more information (figure 11.13).



Figure 11.13, preferred option for the optometrists.

Further research

The conclusions here are most based on the conversations during the tests. The visual communication test do already show a clear preference towards some ideas but for the other two this is a lot more vague. I Think it is best to perform this test with at least 10 more opticians. Then this data can better be analyzed in SPSS withfor example a Categorical Principal Components Analysis. This can help to give a clear visual representation of the preferences of the opticians.

12. Final design

In this chapter the insights from the evaluation will be implemented in the final design.

12.1 Service design

To represent the final service the service overview from chapter 9 is updated with the insights from the interviews. The changed elements will be further explained in this paragraph.

A. Timeframe ophthalmologist

When the AI system sends a patient to the ophthalmologist it also needs to indicate the urgency of the eye problems. This is possible since this data is already stored in the ksyos data set. I discussed this with the AI partner healthplus.ai and they told me that the info found in the AI system can be combined with other textual data from the data set to create a prediction like this.

B.C. Communication with patients

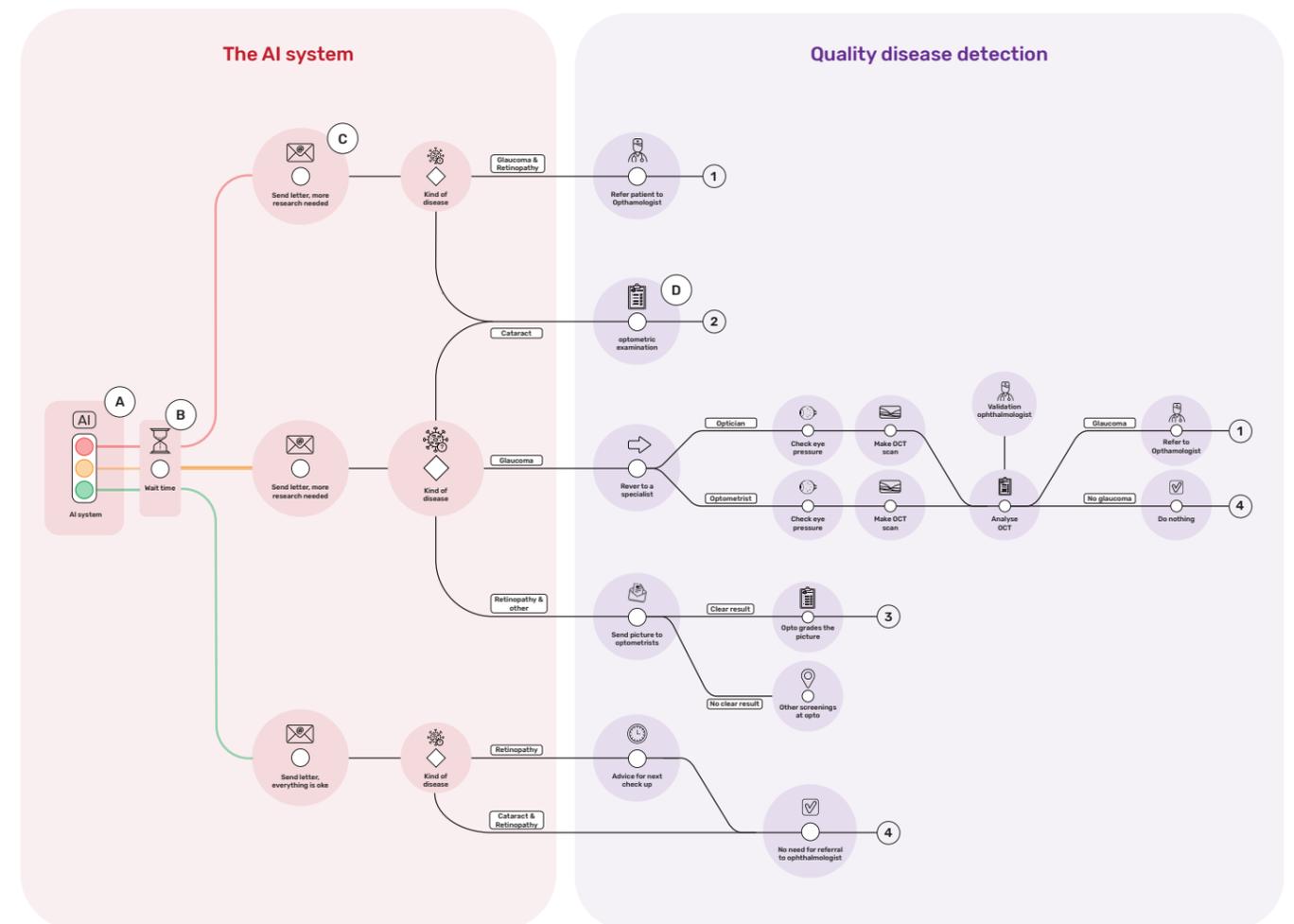
How the AI system should communicate the results with the patient is important. According to the optometrists, who have experience with explaining these kinds of results, a clear and calm approach is best. Patients usually have a lot of questions the moment a disease is discovered. When the specialist is not able to keep the person calm or explain the results clear the patient often goes to the GP and demands to see an ophthalmologist. If the AI system would have this effect on patients both the GP and the ophthalmologist will not be happy with the AI system.

This communication should not be the

responsibility of the optician but organized by Ksyos. It is best that the results are also not presented immediately to the optician, to prevent opticians from communicating the results to the patients. For the right form of communication Ksyos should use lessons can be learned from the disease diagnose programs for breast cancer and colorectal cancer. People go to a specific location just to do the diagnosis test, the results of this test will be sent later to their home. The communication in this letter is clear and neutral, they do not work with colors like green, orange and red. They either say no further research needed or further research needed. When the patient gets the letter for further research needed the next steps are presented clearly. This way the patient gets the feeling these people know what they are doing and they have a good plan for me

D. Cataract

When the AI system suspects cataract, it should not only recommend to do a visus scan but to do a full ophthalmology examination. With cataract it is difficult to see through the lens and other diseases can be developed underneath this blurry lens. The optometrists indicated that they want to see these patients.



12.2 UX design

The focus of this project was not UX design, but based on the research and the tests I have done, some recommendation can be given for the to be developed UX.

Communication patient

Who will be responsible for the communication of the results with the patient is an important question that determined how the UX should look like. I think based on the tests and the conversations with both opticians and optometrists that the optician should not be responsible for this task. In my opinion Ksyos should take this responsibility and communicate the results clear through a letter. In addition to the letter a corresponding website can be made that give the patient some extra info when needed, just like the population screening for colorectal cancer website.

Optometrists

The optometrist will mostly get pictures from the AI system that fall into category orange. This means that according to the algorithm there is something not healthy in these fundus pictures. In most cases the optometrist would recognize immediately if a disease is developing in these eyes and they can give a proper advice. But sometime the AI system (thinks it) sees something the optometrists does not. In this case it is important that the AI system can communicate clearly what it thinks it sees. The optometrists indicated during the tests that they want the algorithm to explain two things, the location of the problem and the medical term for the problem. They also indicated that they want to be able to zoom in to get a better indication of what is happening in the fundus. Figure on the right shows how this AI communication

could look like. Based on this information the optometrist could judge if he agreed with the AI system or not.

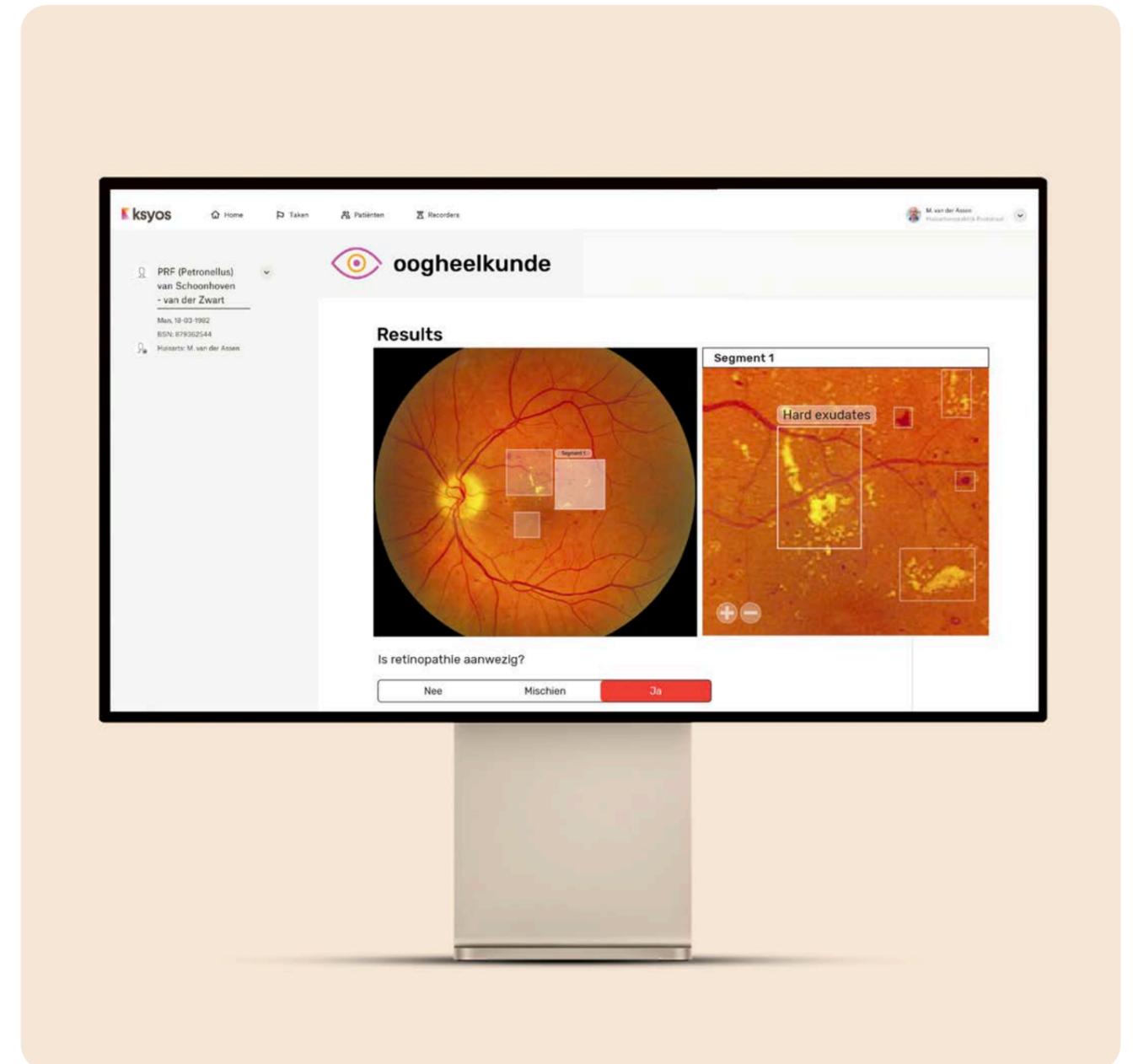
Optician

It could be that later research determines that the optician should be the one who communicates the results with the patient, or that opticians that work at optician stores that also have optometrists available are allowed to view and interpret the results. In these cases, the results of how the AI system should communicate with the optician could be relevant.

The optician wants a simple and clear visual communication. They do not understand the more complex terminology. They prefer a comparison between a normal fundus picture and the taken fundus picture this way they can easily spot the differences. they also prefer a sort of an indication of the elements that the AI system has found in the picture. Figure 12.1 shows how this visual communication could look like. The information about the category the AI system places the patient should be clear without much interpretation needed. The advice itself should be clear and short and it should be easy to interpret what the next step in the diagnosis should be. The optician also preferred a color indication based on a traffic light, this way they can see in a second what the result is.

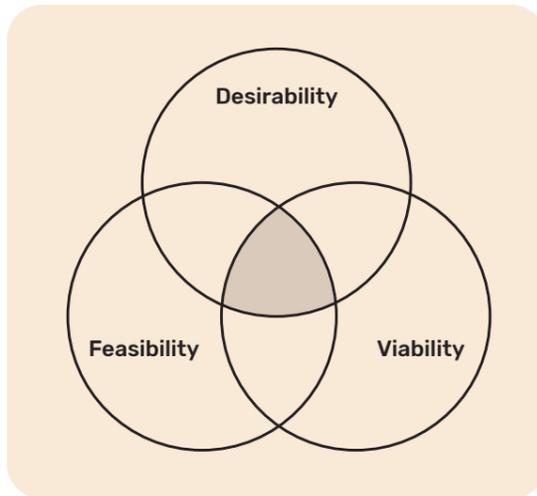


Figure 12.1. Comparison between normal and current picture with white boxes around unhealthy areas.



Conclusion

The goal of the project was to investigate how an AI system can best be fit in the current Ksyos ophthalmology service and whether it is a good idea for Ksyos to integrate the AI system in their current service. To answer this question, we will look at the feasibility, the desirability, and the viability of the concept for Ksyos. An idea that is feasibility, desirable and viable is a good idea.



Feasibility

The technology required for AI eye disease detecting is new but sort of established. It is proven in lab experiments and a couple of pioneer companies like digital diagnostics (US) and Airdoc (china) already have products on the market that could detect eye diseases like retinopathy from fundus pictures.

This research was about how to implement such a technique in a trustable service. Ksyos does have the knowledge and the experience to provide the designed AI service. This AI service build on the strengths of Ksyos ophthalmology, they

already have a network of optometrists and ophthalmologists who they are currently working with. For the development of the AI system, they have an AI partner Healthplus.ai who is capable of creating an AI system that is suitable for the designed service. The AI system also fits with the goal of Ksyos to divide tasks smart between different medical specialists to deliver a affordable and accessible service.

Desirability

Ophthalmologists want more people to be screened on eye diseases. Especially on diseases that are asymptomatic in the beginning stage like glaucoma. These people can be helped a lot better if the disease is discovered earlier. The new AI service will make it possible for a lot more people to detect eye diseases. In the past only optometrists and ophthalmologists were able to detect these diseases, but now also opticians can run a scan for these diseases. This means that a lot more people can be screened on eye diseases.

Optometrists do now the pre-screening for the ophthalmologists, but 90% of the retinopathy screenings they do there is nothing going on. This is not the best way to use their expertise. The new AI system will scan a lot more people but only the people who really need an optometrist are send

to them. This will make the work of the optometrist more interesting and is also necessary because the optometrist indicate that there are more and more people coming to them with eye problems.

The Optician market is changing, new technologies make it possible to measure the visus of a customer online. This means that online stores will pop up and the profit margins potentially will decrease. To justify the higher prices in the store the optician could provide a better service. By scanning the eyes of customers on diseases like glaucoma and cataract could be a motivation to go to the store instead of shopping online.

The AI service makes ksyos more future proof, the AI systems to detect eye diseases are coming and when ksyos wants to maintain its position it should move with its time. Besides this the service could save a lot of money, in the Ksyos AI service 90% of the people who in the current system are helped by an optometrist are now helped by an optician. This means that the labor costs of the service will decrease.

Also, the amount of scans can increase since more locations are capable and willing to make these screens. Ksyos is paid per screening, so more screenings means potentially more money.

Viability

The AI service will be an online platform that opticians and optometrist can access through the internet. This means the opticians or optometrists do not have to pay any new fancy equipment to preform those AI screenings, this makes the service a lot more accessible for them.

The payments for the service will be per scan performed. Ksyos has a large data set of fundus pictures and based on this will create their own algorithm in cooperation with their partner company healthplus.ai. Because they have their own algorithm, they won't have to pay a fee for each scan they make like other companies maybe need to do in the future, this gives them a competitive advantage.

All optometrists and ophthalmologists indicated that the amount of people with eye problems is only increasing. This is partly based on the increasing amount of old people in our society but also based on the amount of time people look at screens. So, the demand for these kind of scans will only increase.

Conclusion

The developed AI service is feasible to make by Ksyos, is a desirable service for the different stakeholders involved, and has viable potential to earn money for Ksyos. For this reason I think it is good service for Ksyos to invest in.

Limitations

There is one limitation I need to mention, the current fundus cameras require for 30 percent of the patients' mydriatic droplets. Ophthalmologists indicated that this percentage in the coming years will decrease rapidly but for now it is still a limitation for the service.

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Yang, Q., Steinfeld, A., & Zimmerman, J. (2019, May). Unremarkable ai: Fitting intelligent decision support into critical, clinical decision-making processes. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems* (pp. 1-11).

Interview list

Judith Schop • optometrist
Riems gort optiek, Alblasserdam

Ilse Augustijn • optometrist
Augustijn Optiek, Oud-Beijerland

Paul van den Berg • optometrist
Van den Berg oogzorg, Sliedrecht

David Klaij • optometrist
Optiek Tom, Rhoon

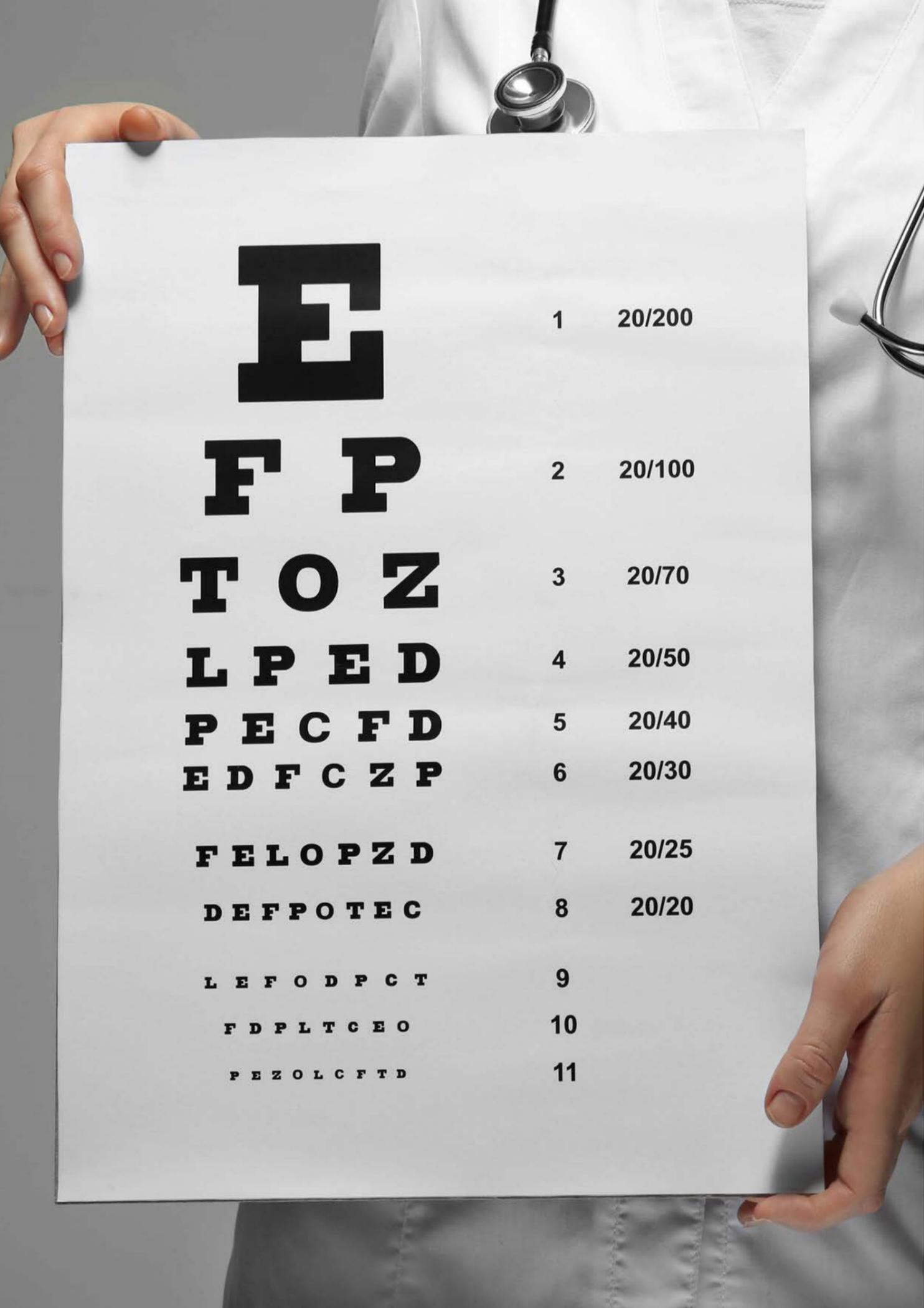
Esther Schuijjer • optometrist
Briede Optiek, Hellevoetsluis

Fokke Postema • ophthalmologist
Eigen BV, Epe

Willem Maat • ophthalmologist
Oog op zuid, Rotterdam

Hans Lemij • ophthalmologist
Het Oogziekenhuis Rotterdam, Rotterdam

Ineke Ruting • general practitioner
Mediis, Gouda



Appendix

A1 Waardekaarten zorg	5
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A1 waardenkaarten zorg

Vrijheid

Zelfbeschikking

- 'Patiënten hebben keuzevrijheid in de zorg die ze krijgen.'
- 'Patiënten houden regie over eigen zorg.'
- 'Mensen zijn vrij om de invulling van hun leven en sterven te bepalen.'
- 'Patiënten zijn een volwaardige gesprekspartner (shared decision making).'
- 'Patiënten worden goed geïnformeerd over de gevolgen van een behandeling (informed consent).'

Professionele autonomie

- 'Zorgverleners zijn opgeleid om professioneel te oordelen en in vrijheid beslissingen te nemen.'
- 'Zorgverleners kunnen het beste beslissen wat de beste zorg is voor een patiënt.'

Privacy

- 'De privacy en vertrouwelijkheid van persoonlijke informatie is gewaarborgd.'
- 'Patiënten hebben recht op bescherming van de persoonlijke levenssfeer.'
- 'Zorgverleners beschermen de privacy met hun beroepsgeheim.'

Rechtvaardigheid

Gelijkheid

- 'Iedereen heeft recht op gelijke gezondheid, ongeacht inkomen, opleidingsniveau of afkomst.'
- 'Alle Nederlanders zijn verzekerd voor dezelfde zorg.'

Solidariteit

- 'Wie gezond is draagt bij aan de zorgkosten van mensen die ziek zijn.'
- 'Wie een hoog inkomen heeft, draagt meer bij aan zorgkosten dan wie een laag inkomen heeft.'
- 'Wie jong is draagt bij aan de zorg voor oudere generaties.'

Wederkerigheid

- 'Wie meer wil betalen voor de zorg, heeft recht op betere zorg.'
- 'Gezond gedrag wordt beloond.'
- 'Mensen hoeven geen hulp te verwachten als ze niet willen bijdragen aan de zorg.'
- 'Mensen houden in hun zorgkeuzes rekening met het draagvlak voor solidariteit.'

Evenredigheid

- 'Ieder mens krijgt de zorg die hem of haar toekomt.'
- 'Mensen kunnen aanspraak maken op zorg maar wie wat krijgt, is maatwerk.'

Continuïteit

Gezondheid

- 'Gezond zijn, is belangrijk voor een volwaardig en gelukkig leven.'
- 'Goede zorg focust op lichamelijk en mentaal welbevinden en het vermogen dagelijkse verrichtingen te doen.'
- 'Goede zorg is voorkomen en genezen van ziekte.'

Zelfredzaamheid

- 'Zorg draagt eraan bij dat mensen kunnen participeren in de samenleving.'
- 'Patiënten kunnen zoveel mogelijk zelfstandig leven binnen hun eigen netwerk.'
- 'Mensen kunnen door ondersteuning een volwaardig leven leiden ondanks hun beperkingen.'

Rust

- 'Bij goede zorg weten patiënten waar ze aan toe zijn door heldere informatie en tijdige communicatie.'
- 'Patiënten kunnen erop vertrouwen dat ze goed verzekerd zijn.'

Kwaliteit

Deskundigheid

- 'In de zorg streven mensen naar de best mogelijke zorg volgens de laatste inzichten en richtlijnen.'
- 'Zorgverleners die zichzelf niet deskundig vinden, roepen de hulp in van deskundige collega's.'
- 'Goede zorg is voorkomen en genezen van ziekte en ondersteuning gericht op levenskwaliteit.'
- 'Zorgverleners zijn altijd bevoegd en bekwaam om hun werkzaamheden uit te voeren.'
- 'Zorgverleners monitoren de kwaliteit van de zorg en zijn hierop aanspreekbaar.'

Veiligheid

- 'Zorgverleners schaden hun patiënten niet.'
- 'Zorgverleners garanderen de veiligheid van de behandelrelatie.'
- 'Zorgverleners volgen protocollen om de veiligheid van patiënten en medewerkers te garanderen.'

Menselijke maat

- 'Bij goede zorg staan de patiënt en oplossingen voor zijn probleem centraal (en niet het systeem).'
- 'Bij goede zorg houden zorgverleners en zorginkopers rekening met verschillen tussen mensen.'
- 'Bij goede zorg houden zorgverleners rekening met de sociale context van de patiënt.'
- 'Zorg is binnen een redelijke termijn en afstand beschikbaar.'
- 'Patiënten hebben behoefte aan een goed bereikbaar, herkenbaar en vast aanspreekpunt.'

Puurheid

Onaantastbaarheid

- 'Ieder mens heeft recht op onaantastbaarheid van zijn lichaam.'
- 'Er zijn grenzen aan in hoeverre er aan het menselijk lichaam gesleuteld mag worden.'

Heiligheid

- 'Ieder mensenleven is beschermwaardig.'
- 'Het is niet aan de mens om te beslissen over leven en dood.'

Zuiverheid

- 'Natuurlijk en authentiek is goed, onnatuurlijk of chemisch is slecht.'
- 'Zorgverleners grijpen niet in zolang mensen het zelf redden.'

Loyaliteit

Saamhorigheid

- 'Een samenleving waarin wij voor elkaar zorgen is een prettige samenleving.'
- 'We zorgen er samen voor dat iedereen zorg en ondersteuning krijgt waar nodig en gewenst.'

Trots

- 'In Nederland is de zorg goed geregeld en dat houden we zo.'
- 'Zorgen voor iemand is dankbaar werk en levert voldoening en waardering op.'

Nut

Zinnig

- 'Zorg is doeltreffend.'
- 'De zorg besteedt de schaarse middelen zo effectief mogelijk.'
- 'Zorg draagt bij aan een productieve samenleving.'
- 'Meer zorg leidt niet altijd tot betere zorg.'

Vooruitgang

- 'Innovaties maken de zorg goedkoper en beter.'
- 'In de zorg blijven organisaties bestaan door zich te blijven ontwikkelen.'

Zuinig

- 'In de zorg gaan mensen zuinig om met beschikbare middelen en wordt verspilling voorkomen.'
- 'Om de zorg betaalbaar te houden, mogen de zorgkosten niet onbeperkt groeien.'

Rekenschap

- 'Zorgverleners verantwoorden zich voor voorgeschreven behandelingen.'
- 'Zorgverleners bewijzen dat gedeclareerde zorg daadwerkelijk geleverd is.'

Hiërarchie

Autoriteit

- 'Wie ziek is, kan zijn lot overlaten aan de zorg.'
- 'Zorgverleners krijgen respect voor hun ervaring en deskundigheid.'
- 'De politiek beslist over de grenzen van de zorg en verschaft legitimiteit aan het zorgstelsel.'

Vertrouwen

- 'Wie zorg nodig heeft, is afhankelijk van andere mensen en vertrouwt op goede zorg.'
- 'Bij goede zorg scheppen zorgverleners realistische verwachtingen bij de patiënt en creëren zij vertrouwen.'
- 'Mensen in de zorg zijn eerlijk en handelen in het belang van de patiënt.'

Traditie

- 'Bij veranderingen in de zorg is het zaak te behouden wat waardevol is.'
- 'Zorgverleners hechten aan behoud van bewezen praktijken.'

Empathie

Betrokkenheid

- 'In de zorg staat persoonlijk contact en erkenning van de patiënt centraal.'
- 'In de zorg zijn medewerkers empathisch en leren de patiënt en zijn behoeften kennen.'
- 'Zorgverleners nemen de tijd voor patiënten en bieden hen een luisterend oor.'
- 'Zorgverleners werken vanuit bevoegdheid.'

Dienstbaarheid

- 'In de zorg staat de beste zorg voor de patiënt altijd voorop.'
- 'Het regelen of geven van zorg is een uiting van naastenliefde.'
- 'Zorgverleners zien het als een roeping om voor anderen te zorgen.'

Geborgenheid

- 'Zorgverlening vindt plaats in een vertrouwde en veilige omgeving.'

Verantwoordelijkheid

- 'We zijn in Nederland verantwoordelijk voor goede zorg voor mensen die dat nodig hebben.'

A2: Clinical decision support systems

One way AI is used in the healthcare sector is by supporting clinicians in making decisions. These tools are called Clinical decision support systems (CDSS). The goal of these systems is to link observations made by the clinician with trained health knowledge of the system, to improve the healthcare. The role of the CDSS is not to take over the role of the clinician but to assist (Berner, 2007...). The combination of the knowledge of the clinician and the knowledge of the CDSS together should create better analysis, which lead to better choices made by clinicians.

An examples of CDSS cooperation between human and machine could be a disease diagnose system. The machine creates a list of potential diseases based on the health observations made by the clinician. Based on the results and the clinicians own expertise he or she decides what is most likely the case. This way the machine and the clinician work together to make a better and quicker diagnoses. Another example is a CDSS that helps creating a cancer treatment plan. The machine decides based on data of previous cases what angles and number of beams is necessary to treat the specific type of brain cancer. The specialist will then review this and creates a treatment plan.

There are mainly two types of CDSS's, knowledgebasedCDSSandnon-knowledge based CDSS's. Knowledge based CDSS are based on rules of code, this mostly contains IF-THEN structures that can determine what kind of disease someone has based of a couple of questions. Because of the

program structure the results of these systems are easy to explain.

Non-knowledge based CDSS are based on machine learning. These systems can teach themselves, they either do this based on past experiences or they discover new patterns themselves out of clinical data. Because these systems are not made of man made code it is difficult to explain why a system makes a certain decision. This is could be a problem for clinicians because the systems need to be reliable and accountable.

For object recognition in images often convolutional neural networks are used. These algorithms are specialised in recognising patterns in images. In the next paragraph convolutional networks will be discussed.

A3: AI & diabetic retinopathy

As discussed in chapter 1 different eye diseases can be discovered by looking at a simple fundus pictures. This does not give only an indication about the percents of a disease but can also indicate how the disease is developing. Some other parties already did research into how this can be used in practice.

Google health a part of Google that focuses on improving health with AI technology did a real-world test of applying a fundus reading algorithm for detecting diabetic retinopathy (DR) (beede, 2020). Their algorithm had a high level of accuracy close to a specialist. Both the sensitivity as the specificity were higher than 90%. In comparison to a specialist the algorithm had a 23% lower false negative rate and a slightly higher false positive rate of 3%. This means the algorithm is better in detecting the disease but sends a couple more people to a specialist that don't have DR.

The trial was in Thailand and consisted of 7600 patients. In the test pictures were taken from both the patient eyes. The taken picture were uploaded to a cloud server that run the analysis. The algorithm showed if DR was present in the eyes and in what stage the DR was developing in the eyes.

The nurses who were in charge of the eye screening were positive about the possibilities. They saw it partly as a learning device and partly as a way to prove their own capabilities to people in higher hierarchy. They usually felt undervalued, but this system gave them a chance to prove themselves. The biggest concerns of the nurses was the extra time this system needed (double

checking), and the higher false positive rate. Another part that needs to be improved is how difficult it is to take a picture the system approves. This led to a lot of frustration and wasted time. Especially because most of the rejected images were readable by humans. According to the research the problems with taking the right picture, lead to 2-4 more minutes per patient. A solution suggested by the researchers was to wait 60 seconds between each picture to let the eyes readjust after the flash, this way the chance of a bad picture a lot lower. But with 150 patients waiting this was not an option (Figure A.1).



Figure A.1

The researchers indicate that future research should look at the accuracy of real life tests. And how to create an end to end service, including the experience of the patient the ophthalmologist and the eye doctor. And make sure it fits into the clinical workflow. In the next paragraph we look at how to integrate AI into the clinical workflow.

A4: Implementation in workflow

The healthcare market is a difficult market to introduce new technologies there are strict workflows and strong hierarchies. Several studies dived into this field to figure the best way to introduce new technical products in this market, and to design products that will be adopted in this market.

The potential of AI in healthcare is big. AI can deliver faster care, deliver more personalised care, can reduce the high costs of the healthcare and can shorten the waiting times (Park, 2019). However the introduction of AI also has some other effects, like Complex organisational changes, changes in hierarchies and communication with clients and within the organisation, and resistance among clinicians. Clinicians could have fears of losing their job to an AI machine, have fear of having to learn new complex skills or have fears about trusting a black box.

The accuracy of an AI system in healthcare is the most important part. The clinicians need to rely on the outcomes the system gives. In some cases this could be difficult because clinicians use more info than can be retrieved from data alone to make their decision (Hartswood, 2003). That is why in these cases their always need to be a human in the loop.

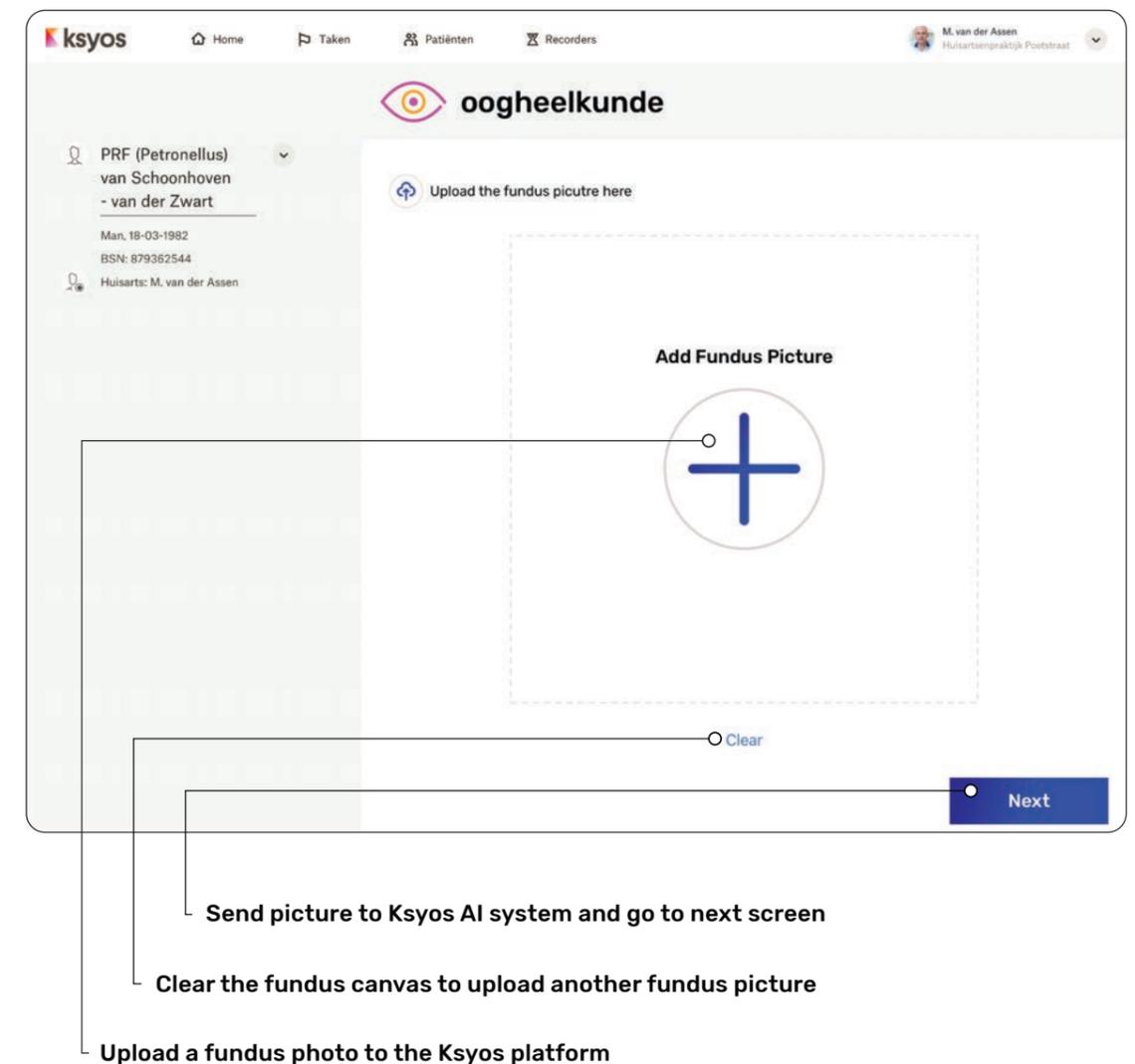
However to create an algorithm that will be used effectively the physical and social context is much more important than just the prediction accuracy. To make a system that will be used, the system need to be designed as an integrated experience (Yang, 2019). Waghlikar created four requirements that a well adopted medical tool should include, besides a high prediction accuracy

(Waghlikar, 2011). The tool should be well adopted to the workflow of the clinicians, The tool should be easy to use for the targeted clinicians and the tool should be able to explain why certain decisions are made.

The workflow is important in the healthcare, it is a sector with strong hierarchies. For a good integration in the workflow the tool should best be unremarkable and only noticed when needed, the new tool should not take more time than the current way of working, and the tool should incorporate workflow dynamics and hierarchies. To make the tool easy to use it is important that it is self-explanatory and don't require any special training for the targeted clinicians. And to make the tool trustable it should be possible to understand and find out how the system works. Clinicians need to be able to play with the system to understand why certain decisions are made (Hartswood, 2003). And to explain to the patient the clinician needs the tools to convince the patient of its diagnoses (beede, 2020).

A5: Interface test 2

Screen 1: Upload screen



Screen 2: regular form

This button will become active when the AI system is done

When the AI system runs the optician/optometrist can fill in the required data

This timer indicates the time it takes until the AI screening is finished

Screen 3: results of the AI system

When there is a potential bias it is indicated here

Place for visual communication of the AI system

Place for explanation of the results of the AI system

Place for the advice the AI system provides to the user

The user can based on the AI advice give his own advice

A6: Cards for test A

List
 Hard exudates
 Hard exudates
 hemorrhage
 Hard exudates
 hemorrhage

1 2 3 4 5 6 7 8

A7: Cards for test B

Is retinopathie aanwezig?
 Nee Mischien Ja

1

kans dat retinopathie aanwezig is
 88%

2

Retinopathie | Er is waarschijnlijk retinopathie aanwezig

3

Retinopathie | Er is waarschijnlijk retinopathie aanwezig

4

kans dat retinopathie aanwezig is
 88%

5

A8: Cards for test C

AI advies: Over 6 maanden nieuwe screening

- R1: Milde achtergrondretinopathie
- M1: Zichtbare maculopathie

Advies specialist: _____

1

AI advies: Over 3 jaar nieuwe screening

Het AI systeem heeft geen elementen in de fundus gevonden die duiden op retinopathie. De kans is heel erg klein dat de ziekte zich binnen 3 jaar tot een ernstige versie omvormd daarom wordt geadviseerd om de volgende scan pas over 3 jaar te doen

Advies specialist: _____

2

AI advies: Over 3 jaar nieuwe screening

Het AI-systeem heeft geen elementen in de fundus gevonden die duiden op retinopathie. De kans is heel erg klein dat de ziekte zich binnen 3 jaar tot een ernstige versie ontwikkeld daarom wordt geadviseerd om de volgende scan pas over 3 jaar te doen.

Advies specialist: _____

3

AI advies: Over 3 jaar nieuwe screening

Advies specialist: _____

4

AI advies: Geen retinopathie, over 3 jaar nieuwe screening

Geen severe retinopathie gevonden
Dit betekent dat de patiënt niet doorverwezen hoeft te worden naar de oogarts. Er kan echter wel deels retinopathie aanwezig zijn. Het AI systeem zal dan adviseren eerder een nieuwe scan te doen.

Mischien severe retinopathie aanwezig
Dit betekent dat het AI-systeem het niet zeker weet. Dit kan komen door een mogelijke bias of een twijfelgeval. De foto kan in dit geval het best verstuurd worden naar een optometrist voor een second opinion.

Mischien severe retinopathie aanwezig
Dit betekent dat het AI systeem retinopathie heeft gevonden in het oog. In dit geval is het aan te raden de patiënt direct door te verwijzen naar de oogarts.

Advies specialist: _____

5

AI advies: Over 6 maanden nieuwe screening

- R1: Milde achtergrondretinopathie
 - 3 hard exudates
 - 2 hemorrhages
- M1: Zichtbare maculopathie
 - 1 hemorrhages

Advies specialist: _____

6

A9: Results of test 3

These are the results from the third tests
The most left numbers are the ones that were preferred the least the most right numbers are the one preferred the most.

Person 1	3	1	7	8	2	5	6	4
Person 2	2	8	5	6	7	4	3	1
Person 3	2	6	7	8	5	3	4	1
Person 4	2	5	6	8	3	7	4	1
Person 5	6	2	3	7	8	4	5	1

Test A optician

Person 1	4	3	2	1	5
Person 2	5	2	4	1	3
Person 3	3	5	2	1	4
Person 4	3	5	2	1	4
Person 5	3	4	1	2	5

Test B optician

Person 1	5	2	3	6	4	1
Person 2	6	1	5	2	4	3
Person 3	6	1	4	5	2	3
Person 4	1	6	3	2	5	4
Person 5	4	1	6	3	2	5

Test C optician

Person 1	3	1	6	4	7	2	5	8
Person 2	1	3	6	7	4	2	5	8
Person 3	3	1	6	4	7	2	5	8

Test A optometrists

IDE Master Graduation

Project team, Procedural checks and personal Project brief

This document contains the agreements made between student and supervisory team about the student's IDE Master Graduation Project. This document can also include the involvement of an external organisation, however, it does not cover any legal employment relationship that the student and the client (might) agree upon. Next to that, this document facilitates the required procedural checks. In this document:

- The student defines the team, what he/she is going to do/deliver and how that will come about.
- SSC E&SA (Shared Service Center, Education & Student Affairs) reports on the student's registration and study progress.
- IDE's Board of Examiners confirms if the student is allowed to start the Graduation Project.

! USE ADOBE ACROBAT READER TO OPEN, EDIT AND SAVE THIS DOCUMENT

Download again and reopen in case you tried other software, such as Preview (Mac) or a webbrowser.

STUDENT DATA & MASTER PROGRAMME

Save this form according the format "IDE Master Graduation Project Brief_familyname_firstname_studentnumber_dd-mm-yyyy". Complete all blue parts of the form and include the approved Project Brief in your Graduation Report as Appendix 1 !

family name	<u>de Leve</u>	Your master programme (only select the options that apply to you):
initials	<u>W.A.</u> given name <u>Ward</u>	IDE master(s): <input checked="" type="radio"/> IPD <input type="radio"/> Dfl <input type="radio"/> SPD
student number	<u>4357507</u>	2 nd non-IDE master: _____
street & no.	_____	individual programme: _____ (give date of approval)
zipcode & city	_____	honours programme: <input type="radio"/> Honours Programme Master
country	_____	specialisation / annotation: <input type="radio"/> Medisign
phone	_____	<input type="radio"/> Tech. in Sustainable Design
email	_____	<input type="radio"/> Entrepreneurship

SUPERVISORY TEAM **

Fill in the required data for the supervisory team members. Please check the instructions on the right !

** chair	<u>Nazli Cila</u>	dept. / section:	<u>HICD</u>
** mentor	<u>Deborah Nas</u>	dept. / section:	<u>MOD</u>
2 nd mentor	<u>Jiska de Wit</u>		
organisation:	<u>Ksyos</u>		
city:	<u>Amstelveen</u>	country:	<u>Netherlands</u>

Chair should request the IDE Board of Examiners for approval of a non-IDE mentor, including a motivation letter and c.v..

- ! Second mentor only applies in case the assignment is hosted by an external organisation.

- ! Ensure a heterogeneous team. In case you wish to include two team members from the same section, please explain why.

comments (optional)

Procedural Checks - IDE Master Graduation

APPROVAL PROJECT BRIEF

To be filled in by the chair of the supervisory team.

chair _____ date ____ - ____ - ____ signature _____

CHECK STUDY PROGRESS

To be filled in by the SSC E&SA (Shared Service Center, Education & Student Affairs), after approval of the project brief by the Chair. The study progress will be checked for a 2nd time just before the green light meeting.

Master electives no. of EC accumulated in total: _____ EC

YES all 1st year master courses passed

Of which, taking the conditional requirements into account, can be part of the exam programme _____ EC

NO missing 1st year master courses are:

List of electives obtained before the third semester without approval of the BoE

name _____ date ____ - ____ - ____ signature _____

FORMAL APPROVAL GRADUATION PROJECT

To be filled in by the Board of Examiners of IDE TU Delft. Please check the supervisory team and study the parts of the brief marked **. Next, please assess, (dis)approve and sign this Project Brief, by using the criteria below.

- Does the project fit within the (MSc)-programme of the student (taking into account, if described, the activities done next to the obligatory MSc specific courses)?
- Is the level of the project challenging enough for a MSc IDE graduating student?
- Is the project expected to be doable within 100 working days/20 weeks ?
- Does the composition of the supervisory team comply with the regulations and fit the assignment ?

Content: APPROVED NOT APPROVED

Procedure: APPROVED NOT APPROVED

comments

name _____ date ____ - ____ - ____ signature _____

A-eye: Implementation of AI in eye disease detection project title

Please state the title of your graduation project (above) and the start date and end date (below). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

start date 29 - 03 - 2021 end date 24 - 08 - 2021

INTRODUCTION **

Please describe, the context of your project, and address the main stakeholders (interests) within this context in a concise yet complete manner. Who are involved, what do they value and how do they currently operate within the given context? What are the main opportunities and limitations you are currently aware of (cultural- and social norms, resources (time, money,...), technology, ...).

Ksyos is a Dutch digital health care institute, that uses new technologies to assist healthcare professionals like GPs. These new technologies could make it possible to diagnose certain diseases at home or at the GPs office instead of at a specialist. Examples are a home taken picture of a brown spot on your skin can be send to your GP for dermatologic examination, or an easy to use ECG set you pick up at your GP instead of going to a cardiologist. As a result, the patient's waiting time and the workload of specialists will be decreased.

The context of this project focuses on the diagnoses of eye diseases especially diabetic retinopathy. Diabetic retinopathy is an eye disease that can cause loss of vision and blindness. In the USA 28.5% of all people with diabetes suffer from diabetic retinopathy (Gulshan, 2016). The Loss of vision can be prevented by regular screening and the right treatment (American Academy of Ophthalmology, 2010). Kysos is developing an AI system that can determine from a photo of diabetic retinopathy is developing in the eyes of the patient (figure 1). These photos will not be taken by a specialist but by an optometrist, this will shorten the waiting time and make healthcare more accessible (figure 2). However, they indicate that many AI applications in healthcare often fail to live up to their expectations (Yang, 2019). The project will focus on implementing and designing an AI service design that fit in the current clinical workflow of the different stakeholders.

Stakeholders:

- Optometrist: They need to make the right decisions in cooperation with the AI system. The system should be easy to interact with and give clear elaborated results.
- General practitioners: They need to count on qualitative system that they can trust and validate to explain the results to the patient.
- Eye specialist: They want to reduce workload without feeling the quality decreases. Like to focus on more challenging eye diseases. Need to be able to quickly check the results.
- Ksyos: They want to develop a new AI based service that make it easier to screen more people in a shorter time at a more affordable cost without losing quality.

Gulshan, V., Peng, L., Coram, M., Stumpe, M. C., Wu, D., Narayanaswamy, A., ... & Webster, D. R. (2016). Development and validation of a deep learning algorithm for detection of diabetic retinopathy in retinal fundus photographs. *Jama*, 316(22), 2402-2410.

Yang, Q., Steinfeld, A., & Zimmerman, J. (2019, May). Unremarkable ai: Fitting intelligent decision support into critical, clinical decision-making processes. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems* (pp. 1-11).

Ophthalmoscopy, D., & Levels, E. T. D. R. S. (2002). International clinical diabetic retinopathy disease severity scale detailed table.

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introduction (continued): space for images

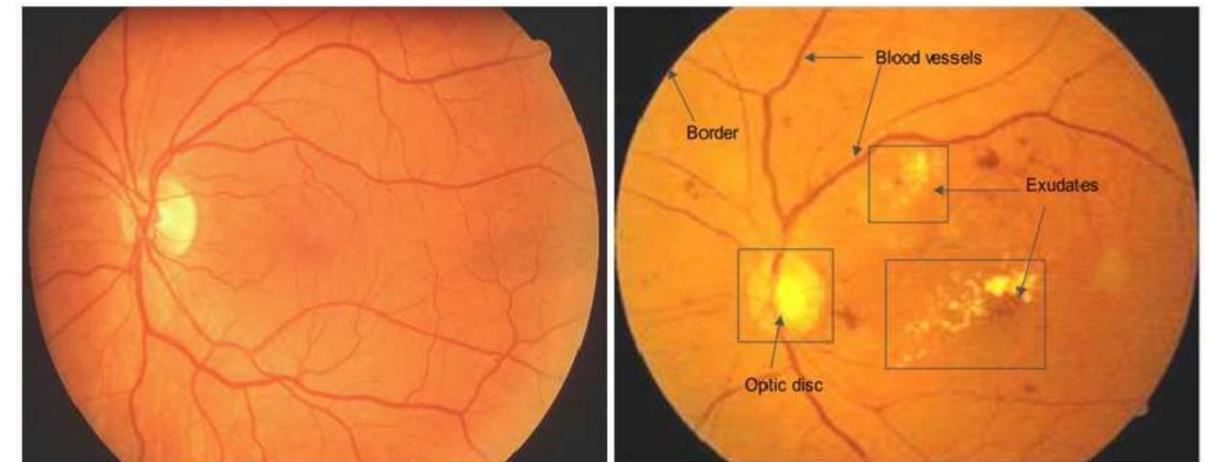


image / figure 1: a) normal fundus picture (back of the eye) b) fundus picture of a patient with diabetic retinopathy

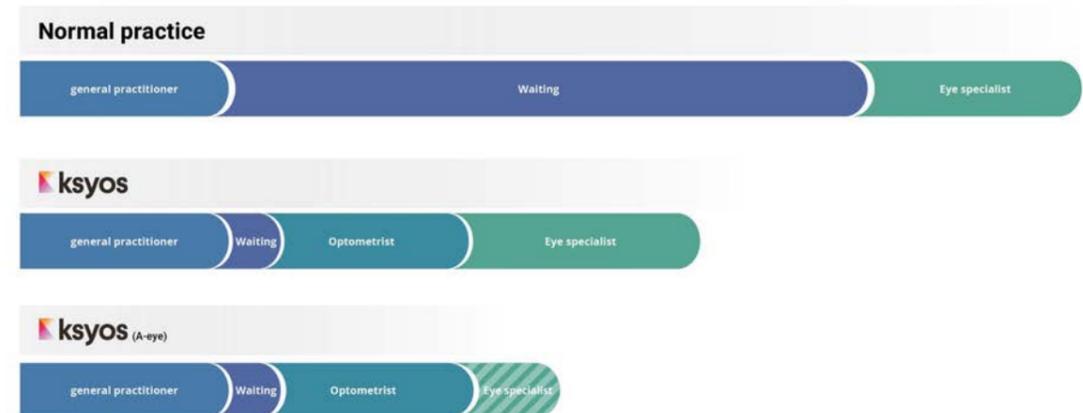


image / figure 2: a) normal way of diagnosis b) the current practice of Ksyos c) the new AI service of Ksyos

PROBLEM DEFINITION **

Limit and define the scope and solution space of your project to one that is manageable within one Master Graduation Project of 30 EC (= 20 full time weeks or 100 working days) and clearly indicate what issue(s) should be addressed in this project.

Previous trials have shown that implementation of AI systems in healthcare can be difficult (Wagholikar, 2012). There are several reasons why these introductions have failed, like no good integration in the current clinical workflow, difficult to validate the results and too complex to use the system. The problem that needs to be solved in this project is how to successfully introduce an AI system to detect retinopathy in the difficult healthcare workflow.

Wagholikar, K. B., Sundararajan, V., & Deshpande, A. W. (2012). Modeling paradigms for medical diagnostic decision support: a survey and future directions. *Journal of medical systems*, 36(5), 3029-3049.

ASSIGNMENT **

State in 2 or 3 sentences what you are going to research, design, create and / or generate, that will solve (part of) the issue(s) pointed out in "problem definition". Then illustrate this assignment by indicating what kind of solution you expect and / or aim to deliver, for instance: a product, a product-service combination, a strategy illustrated through product or product-service combination ideas, In case of a Specialisation and/or Annotation, make sure the assignment reflects this/these.

This project will focus on designing a service that will make the Implementation of the AI system in the current healthcare market a success.

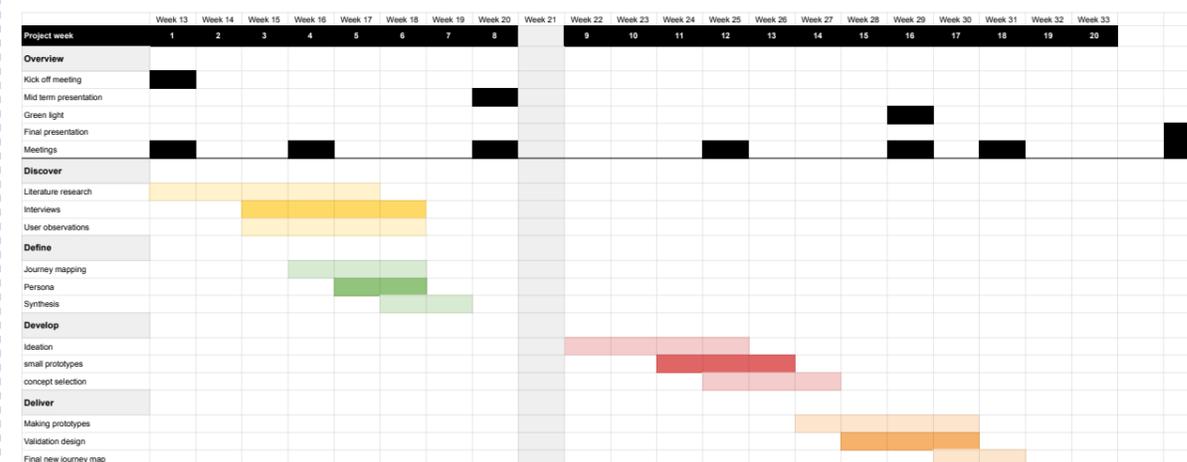
To create a service that will be adopted and used by the different clinicians in an effective way first research needs to be done. I will research the current workflow of the different stakeholders, how to make the outcomes of an AI system valid/explainable, how to create a good and clear human-computer interaction and how should this information be communicated with the patient. The information for this research will be gathered by literature research, talking to experts, and interviewing/observations of the different stakeholders.

Based on this research I expect to create a journal map of the service design with different touch-points. The touch-points the different stakeholders have with the system will be further developed into concepts. UX-prototypes of those concepts will be tested to deliver a validated experience.

PLANNING AND APPROACH **

Include a Gantt Chart (replace the example below - more examples can be found in Manual 2) that shows the different phases of your project, deliverables you have in mind, meetings, and how you plan to spend your time. Please note that all activities should fit within the given net time of 30 EC = 20 full time weeks or 100 working days, and your planning should include a kick-off meeting, mid-term meeting, green light meeting and graduation ceremony. Illustrate your Gantt Chart by, for instance, explaining your approach, and please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any, for instance because of holidays or parallel activities.

start date 29 - 3 - 2021 end date 24 - 8 - 2021



MOTIVATION AND PERSONAL AMBITIONS

Explain why you set up this project, what competences you want to prove and learn. For example: acquired competences from your MSc programme, the elective semester, extra-curricular activities (etc.) and point out the competences you have yet developed. Optionally, describe which personal learning ambitions you explicitly want to address in this project, on top of the learning objectives of the Graduation Project, such as: in depth knowledge a on specific subject, broadening your competences or experimenting with a specific tool and/or methodology, Stick to no more than five ambitions.

During my electives I did a couple of AI related courses. I think there is great opportunity for industrial design students to bridge the gap between the AI systems and the user experience. During the course we learned a lot about the opportunities of AI, but as indicated before the implementation of AI in the real world usually has some complications. I think this project is a good opportunity to learn more about how to implement AI in a real-world scenario. The competence I want to prove during this project is the ability to develop a complex product/service based on a lot of different criteria. Besides that the project has a lot of different stakeholders with different needs. The company is able to provide easy access to the different stakeholders. This creates another great learning opportunity to develop this skill even more.

FINAL COMMENTS

In case your project brief needs final comments, please add any information you think is relevant.