Scottish Optometry Pilot Study

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Version 7 8 November 2021

Report of a study funded by the Scottish Funding Council as part of the Edinburgh City Initiative (Data-Driven Innovation Centre grant number GZ9261).

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Abstract

The Optometry Pilot Study was motivated by three factors: (1) the need to build back better after the pandemic, e.g. by addressing the backlog of referrals to secondary care, (2) the growing pressure on eye-care services because of the aging population and developments in treatment and (3) advances in the AI-powered systems aiding the diagnostic interpretation of images of patients' eyes. As background, we present a summary of these pressures and trends, and describe the extension of optometrists' healthcare roles in Scotland since 2006. We focus on two technological drivers: the emergence of AI diagnostic-decision support and the sharing of high-quality retinal images. The study was conducted in conjunction with the SCONe project – the Scottish Collaborative Optometry-Ophthalmology Network e-research – which is establishing a retinal imaging research resource for Scotland. Our study, conducted in 2021, interviewed 18 optometrists and 5 ophthalmologists to discover their experiences and expectations surrounding the use of ocular images for patient care. Our analysis of these interviews is presented. Those interviewed prioritised patient care, had a widespread willingness to adopt new methods and technologies, but identified several concerns and constraints that need to be addressed. We summarise these issues and identify their common factors. We note the limitations of the study and propose further investigations to mitigate these limitations. We conclude by proposing actions to help SCONe and ocular healthcare in Scotland meet their goals.

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1 Introduction

The Optometry Pilot Study (OPS) investigated the socio-technical, professional and organisational aspects of optometry in Scotland, focusing on the potential for service innovation in ocular healthcare becoming possible through advances in AI methods for ocular image interpretation [Campbell *et al.* 2021][1]. The study was conducted in collaboration with SCONe – the Scottish Collaborative Optometry-Ophthalmology Network e-research project[2]. SCONe is establishing a research resource including a national repository of ocular images to enable early identification of eye disease, improve clinical outcomes, uncover novel biomarkers predictive of ocular and systemic diseases by accelerating the development, tuning and validation of AI methods and by providing a comprehensive source for human investigations, education and training that accurately reflects the Scottish population. By gathering optometrists' views on data sharing and AI-powered methods we are able to report expectations, concerns, opportunities and requirements relevant to SCONe's planning and future outcomes. These findings have wider applicability, informing the implementation of future optometry-ophthalmology service innovations in Scotland and beyond. This revised and final report summarises our findings and raises some implications for policy and practice as well as opportunities for further work which we aim to discuss with stakeholders and a wider range of interested parties[3]. The research was conducted between February and July 2021 and was funded by the Scottish Funding Council (SFC) as part of its *build-back-better* campaign[4]. This required a local focus and short duration.

The need for this study was informed by our awareness, in part from personal experience,[5] of the intense and growing pressures on ophthalmology departments due to the success of their treatments in preserving sight as well as the aging population. Learning that SCONe, our study partner, was establishing a research resource, the potential of retinal-image sharing and for AI decision-support assistants was apparent. But we were aware of the challenges and concerns introducing such systems generate. The restrictions imposed in response to Covid-19 intensified the need and highlighted opportunities. This study accordingly considered how best to help the professionals delivering eye healthcare in Scotland – predominantly the optometrists who provide the front-line support. We hope that the results of this study will help those setting up SCONe and those revising the eye healthcare services avoid pitfalls as they deliver healthcare organisational and technical infrastructure that will be accepted by all those concerned and prove beneficial.

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[1] Written on behalf of the American Academy of Ophthalmology Task Force on Artificial Intelligence
[2] **S**cottish **C**ollaborative **O**ptometry-**O**phthalmology **N**etwork **e**-Research (**SCONe**) https://www.ed.ac.uk/clinicalsciences/ophthalmology/scone
[3] An earlier version of this report was circulated to respondents and our advisors for validation.
[4] This funding is administered and supported by the Data-Driven Innovation (**DDI**) centre in the University of Edinburgh https://ddi.ac.uk/.
[5] Malcolm's story https://www.ed.ac.uk/clinical-sciences/ophthalmology/scone/scone-stories/malcoms-story

Community optometrists are the first port of call for eye problems in Scotland - possibly the busiest primary healthcare service. An eye examination in Scotland provides a full health check of the eyes and includes the prescribing of refractive correction – spectacles or contact lenses. Optometrists are highly skilled at detecting eye problems and signs of other significant health conditions. They can treat a wide range of eye conditions and refer patients to the hospital eye service for secondary care when required. Optometry practices are mainly located in the high streets and shopping centres of cities and towns, so that most patients in Scotland are within a reasonable distance of such a practice. Centres of ophthalmology expertise are located in hospitals in a few major cities. One consequence of the geographic distribution of ophthalmic centres is that patients in smaller towns and rural areas[6] face significant time and money travel costs particularly when ferry trips are needed[7]. The cumulative social and economic value of such centres in preventing vision loss was estimated at £1.6 billion in Disability-adjusted life years (DALY) – the number of productive and active years lost[8] for Scotland [Pezzullo *et al.* 2018]. The impact of missing such appointments was exposed by the Covid-19 pandemic – analysis of data from 27 NHS healthcare trusts in England showed a doubling in the rate of being declared legally blind when patients missed appointments [Thomas *et al.* 2020]. Even in compact and well-connected regions like Edinburgh and the Lothians, travel difficulty impacts outpatient attendance by the most vulnerable with potentially serious consequences.

In both central and peripheral settings, early and accurate judgements as to when a referral is needed are very significant:

1. Earlier referral may save full vision; late referral and diagnosis delays – when signals latent in images are missed until a later appointment – may result in sight loss,
2. Erroneous referral (e.g. due to misinterpretation of images) imposes stress on patients and may require them to endure difficult travel. It also imposes an avoidable load on secondary-care ophthalmology resources.

Effective, efficient and sustainable service improvements based on improving the handling and assessment of ocular images, such as the introduction of AI decision making assistants[9] and adjustments in the working practices linking optometrists with ophthalmologists are envisaged in the near future. The OPS interviews and analysis focused on this potential to highlight opportunities and reveal impediments to such service innovations. OPS focused on human factors and the socio-technical context. It did not assess the AI research nor the IT system requirements, though these need to be carefully considered to achieve *sustainable* improvements.

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[6] Remote rural areas in Scotland have a higher proportion of older people in their population (who are more likely to have ocular disease). https://www.gov.scot/publications/rural-scotland-key-facts-2021/pages/2/

[7] Some *rural* optometrists are more than three hours by road from centres of expertise. Patients on islands have the additional limits of ferry schedules. In extreme cases this requires an overnight stay, and because of their condition most patients require someone else to drive them; imposing a demand on ambulance services or on carers who may themselves be aging. Optometrist P28, who works in the Highlands highlighted the challenge posed by physical distance for *"patients who are maybe hours … or a flight away from a hospital and…it's very difficult sometimes making decisions…when there's a lot riding on It ,… you have to be really sure that what you're telling them to get a flight for is right"*

[8] The annual cost in 2013 of ocular healthcare in Scotland is given as £292 and £484 million for direct and indirect costs in [Pezzullo *et al.* 2018]. Since then, costs and numbers (aging population) have increased, and treatments continue for longer because they have improved.

[9] Selected technical terms and abbreviations may be found in Appendix A page 41.

The provision of ocular primary care by optometrists and its embedding in the health system is complex. There are sensitive ethical issues such as patient privacy. Nevertheless, much has already been achieved by the gradual introduction of digital tools to these settings. The successful introduction of new methods to primary care requires an evolutionary, incremental approach [Pagliari 2021]. This suggests that existing attitudes, capabilities, practices, organisations, systems and technologies need to be carefully taken into account as optometrists provide primary healthcare. The OPS study has undertaken initial steps in the required co-design and co-development of the interlocking professional, organisational, ethical and technical service innovations that will lead to a sustainable and widespread evolution of ocular healthcare in Scotland.

Five trends combine to increase the pressure for innovation in ocular healthcare.

1. The aging population as the prevalence of diseases requiring treatment increases with age.
2. Advances in medical practice open up opportunities for new treatments and ways of mitigating and managing the progression of chronic eye disease over extended durations. As treatments sustain sightedness for increasing durations, the number of patient visits for treatment grow; this threatens to overwhelm eye healthcare service providers.
3. Ocular imaging is increasingly used and more sophisticated imaging modalities such as optical coherence tomography (OCT) are becoming common place within primary care optometric practice, delivering much more information about patients' eyes. It becomes infeasible for an optometrist to examine every part of every image that *may* be significant on every patient visit.
4. AI-powered algorithms already exist to extract significant information from those images and more will emerge [Campbell *et al.* 2021]. As *decision support assistants* they will lead to earlier detection of opportunities for vision-saving treatments and to the recognition of new signals and conditions. They can potentially scan all images, drawing attention to cumulatively significant signals. Longitudinal studies of image archives, such as that being established by SCONe, can advance medical research by discovering new early indicators of a condition.
5. Widespread high-performance secure digital communication offers new opportunities for collaboration between optometrists and ophthalmologists – for example remote consultations reviewing images obtained by an optometrist under tele-ophthalmology trials in NHS Scotland, leading to earlier triage and reduced patient referral journeys [Ghazala *et al.* 2020, Poyser *et al.* 2019].

The COVID-19 pandemic has exacerbated these pressures with intense catch-up workloads. It has also triggered a readiness to use remote consultations [Pagliari 2021]. For remote healthcare consultations *in general* this has led to a theoretical model, PERCS, and guidelines on how to plan and evaluate such services that takes into account the full complexity of practical and ethical issues [Greenhaigh *et al.* 2021] summarised as Figure 1. They partition the issues that must be considered in order to deliver a fair, ethical, comprehensive and sustainable remote consultation service into 14 themes. At least ten of these themes would be pertinent when planning or evaluating such consultations between ophthalmologists and optometrists about patients' conditions presenting in their practice.

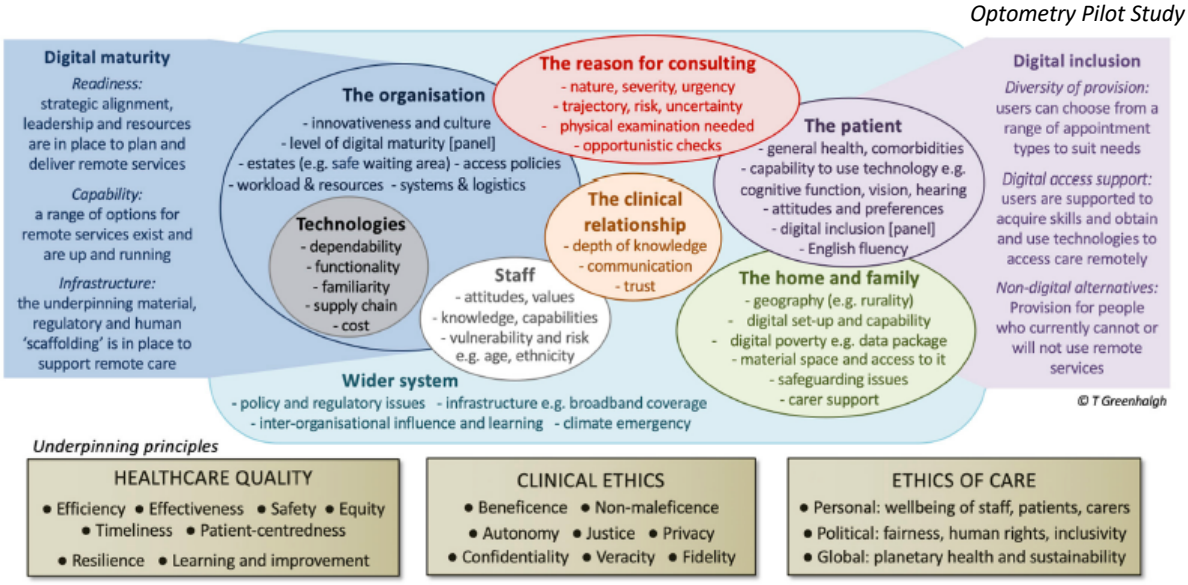

Figure 1: The PERCS (Planning and Evaluating Remote Consultation Services) framework and underpinning principles of healthcare quality and ethics (Figure 1 in Greenhaigh et al. 2021).

Campbell *et al.* [2021] state the average delay from a peer-reviewed publication identifying an AI-powered improvement to wide deployment in healthcare is 17 years assuming the healthcare infrastructure[10] supports the intervention. The close relationship between research and health institutions in Scotland offers the promise of more rapid deployment and adoption.

An important contribution to this in Scotland is the formalisation of the existing optometry provision in 2006 through the General Ophthalmic Service (GOS)[11], which made eye examinations free to everyone. This included providing optometrists with funding for fundus cameras and for their use in primary healthcare, i.e., fundus images are obtained and analysed as part of the eye-examinations of the over 60s and attract a higher GOS eye-examination fee [Jonuscheit *et al.* 2019]. This strengthened the professional ethos, including extra training and criteria in qualifying examinations to enable and sustain the primary healthcare role[12], with relevant standards, governance and incentives. It initiated the accumulation of ocular images in optometry practices and set up a consistent referral system from optometry practices to NHS ophthalmology centres – a critical element of the healthcare infrastructure [Jonuscheit *et al.* 2019].

Drawing on 'implementation science', Campbell *et al*. 2021 flag "*the implementation gap*". They identify issues that must be addressed before an improvement *that is already a success in research trials* can be successfully and sustainably made available for everyone served by a healthcare service. They assume the relevant healthcare infrastructure already exists. Figure 2, taken from their paper, summarises the hurdles to be overcome. OPS begins to map viable paths addressing those hurdles – see sections 2.3 and 3.1. It also identifies further

[10] The many organisations and procedures, the digital systems, services and tools enabling them and the many individuals in different roles combining them for the benefit of patients.
[11] General Ophthalmic Service https://beta.isdscotland.org/topics/eye-care/general-ophthalmic-service/
[12] Eye tests are free in Scotland.

questions that may need to be addressed to help ocular healthcare providers in Scotland navigate those paths – see section 3.2.

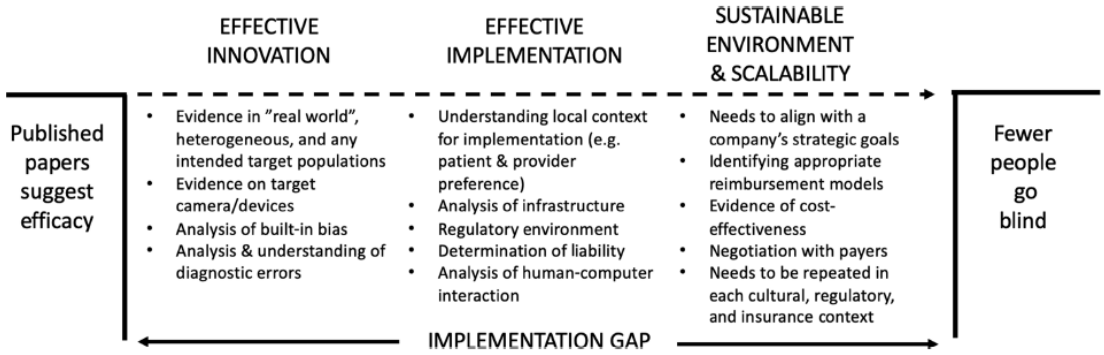

Figure 2: The implementation gap from [Campbell et al. 2021]. The OPS research addresses relevant topics, particularly those in the central column.

Readers not familiar with **optometry** and **ophthalmology** healthcare may appreciate an overview of the ocular healthcare infrastructure; others may skip to our introduction to AI decision support[13]. Many people visit optometrists (formerly known as 'opticians' or 'ophthalmic opticians') to get their eyes tested. As part of an eye examination, optometrists measure refractive defects in the eyes and prescribe corrective lenses as required. The college of optometrists states "*An optometrist can do much more than prescribe glasses. They examine the eyes to detect vision problems, injury, eye disease and even some general health problems. They can provide advice on maintaining good eye health and can give you information and help answer questions on all things eye and vision related*."[14] Optometrists provide critical primary eye healthcare for millions [GOS Executive 2018, Campbell *et al.* 2021].

During a consultation, optometrists assess their patients' eyes to detect signs of incipient disease. They treat and manage many conditions within community practice and refer to an ophthalmologist for secondary care when required. The diseases of principal concern[15] (all of which increase in prevalence and severity with age) are:

1. **Diabetic retinopathy** (DR) is one of the leading causes of permanent blindness in the working-age population, affecting roughly a quarter of the more than 400 million people with diabetes worldwide [Campbell *et al.* 2021]. As the development of DR affects blood vessels which can be visualised in the eye, retinal screening is recommended. This may be conducted by optometrists or ophthalmologists in Scotland. AI decision-support for this screening has proved cost-effective [Scotland *et al.* 2007]. However, there are questions about its deployment, about whether expensive cameras and trained image-takers are needed [Campbell *et al.* 2021]. Because of the GOS agreement the cameras and training are potentially available in Scotland. An automated grader is processing 600 patients a day as part of the NHS Scotland Diabetic Retinopathy Screening Service[16].
2. **Glaucoma** is a group of conditions, most of which are characterised by slow progressive damage to the optic nerve. It is often asymptomatic in the early stages. There are many different types of glaucoma with complex underlying

[13] A summary of definitions and abbreviations is tabulated in Appendix A page 41.
[14] https://www.college-optometrists.org/the-college/media-hub/news-listing/the-role-of-your-optometrist.html
[15] We omit neonatal diseases.
[16] https://www.ndrs.scot.nhs.uk/wp-content/uploads/2019/11/DRS-Annual-Report-2018.pdf

processes, making it difficult to develop effective diagnostic routines and AI algorithms. Optometrists in Scotland use a combination of assessments e.g. evaluation of optic nerve head, evaluation of anterior chamber angle and depth, measurement of intraocular pressure, measurement of central corneal thickness, and field-of-vision tests (perimetry) to detect glaucoma.[17].

3. **Age-Related Macular Degeneration** (**AMD**) has two forms: neovascular (nAMD) or wet AMD and non-neovascular (nn AMD) or dry AMD. It is the world's most prevalent age-related blinding disorder – the estimated world-wide number of people afflicted with AMD is 196 million in 2020 rising to 288 million by 2040 [*ibid*]. It requires treatment when it is exudative – fluid is leaking from blood vessels and damages the macula, part of the retina. Optometrists can detect wet AMD during eye examinations. Assessment using OCT normally follows at ophthalmology centres. The increasing use of OCT by optometrists in Scotland may enable earlier detection or more certain judgements. False referrals, in non-exudative cases imposes unnecessary stress on patients and their supporters and an unnecessary triage load on ophthalmology centres. AI decision support assistants have recently demonstrated success in differentiating between exudative and non-exudative OCT images [*ibid*]. Investigation is still needed to determine the cost-benefits and sustainability of such systems. Investigations are underway into performing that triage decision support based on fundus images [*ibid*]. The required fundus cameras are supplied to all optometrists in Scotland who are funded to use these with older patients – making this a potentially useful innovation in Scotland.

The optometrist will build up an assessment of the risk to a patient of a disease by combining multiple sources of information possibly over several visits. This depends on directly examining an eye with slit lamp biomicroscopy and frequently these days by taking and examining digital images of the eye. A number of devices and observational methods are in common use:

1. **Fundus cameras**, the fundus is the inside, back surface of the eye. It is made up of the retina, macula, optic disc, fovea and blood vessels. A fundus camera produces high-resolution coloured digital images of the fundus through undilated and dilated pupils.
2. **Optical Coherence Tomography** (**OCT**) is an imaging technique that uses low-coherence light to capture micrometre-resolution, two- and three-dimensional cross-sectional images of the eye. It captures images of the posterior eye (fundus) and also has the ability to image the anterior eye (cornea and lens).
3. **Wide-field retinal imaging** gives the opportunity to simultaneously visualise the central and peripheral retina in a single session.
4. **Perimeter instrument** measures the angular extent and the characteristics (e.g., presence of scotoma) of the visual field, e.g., by displaying dots on a screen and noting which ones a patient detects.
5. **Angiography** images blood flow and is used to detect ischaemia and haemorrhaging.

[17] The NICE guidelines require all the following tests: visual field, optic nerve assessment through fundus examination, IOP measurement using Goldmann applanation tonometry, peripheral anterior chamber assessment using gonioscopy and central corneal thickness measurement. See 1.2.1 in https://www.nice.org.uk/guidance/ng81/resources/glaucoma-diagnosis-and-management-pdf-1837689655237

6. **Autofluorescence** images the presence of natural fluorophores, which help diagnose age-related macular degeneration.

Some devices are multifunctional. Most devices preserve a digital record that may be stored as a file locally or sent (suitably protected) to other places in the healthcare system, e.g., when referring a patient via the SCI Gateway (the NHS Scotland infrastructure providing electronic exchange of clinical information between primary and secondary care) or for archiving in SCONe's repository.

When optometrists suspect there is a condition that requires treatment beyond their scope of practice, they may refer their patient to the ophthalmologists. Ophthalmologists have completed full medical training and then specialised in ophthalmology. They may specialise further to treat a subset of the eye diseases. Ophthalmology centres include teams of e.g. retinal photographers and specialist nurses, specialist technicians and specialist equipment as well as clinical and hospital facilities.

AI decision support is developing in many fields, here we provide an introduction for ocular healthcare taken from Campbell *et al.* [2021]. They say, "*The emergence of artificial intelligence (AI) in medicine has raised hopes that this technology, which has demonstrated the ability to make medical diagnoses from images, might reduce inequalities in access to ophthalmologic diagnosis and ultimately care. … improve the efficiency of care delivery …*" (p2). These systems use combinations of logic and machine learning to interpret digital images. They *may* deliver erroneous results, e.g., because the training data did not represent the current patient well. Consequently, for the foreseeable future in Scotland, they would only be used as decision-support assistants, operating by pointing out or interpreting features in an image to an optometrist. As is the case without AI, the optometrist would take into account other information about the patient then use their experience and training to judge how to interpret the AI suggestion. Training and consultation would be needed to develop confidence in using such AI assistance.

Accessing the data needed for **research** to develop AI decision support for healthcare takes two forms: **consented** and **non-consented** studies. Both require ethical approval which balances patient benefits against risks of data misuse[18]. Both are constrained by local rules and culture.

In a **consented study** a relatively small number of subjects are selected and give their informed consent for that specific study. They then provide information and are subject to examinations and observations for the duration of the study. The results (e.g., a machine-learning training data set) are limited to the characteristics of that study. Fore-runners that may indicate disease risk are limited to the disease being studied and by the duration of the study.

A **non-consented study**, as conducted in [Thomas *et al*. 2020] uses data collected for healthcare purposes without the patients' consent for it to be used for any purpose other than *their* healthcare. The ethical regulators require convincing that the potential benefits to future healthcare warrant that *exceptional* use. They also constrain the research procedures so that all the privacy controls and security are

[18] Formalised in the Caldicott process in Scotland [NHS 2010]

implemented to their satisfaction, as described for the Scottish collection of medical images, PACS, in [Robertson *et al.* 2016].

SCONe is setting up non-consented context for research with appropriate Public Benefit Privacy Panel approval[19]. This will provide the potential for studies that span the full range of human diversity in Scotland and can investigate any eye or systemic disease that occurs in Scotland. Such research can include longer-term longitudinal studies that could yield new ways of interpreting ocular images and earlier disease-risk detection enabling preventative treatments to the benefit of future patients.

Section 2 reports our findings from the interviews and consultations with optometrists and ophthalmologists. We highlight the major observations and recognise significant consistent reservations. We conclude in section 3 with a consolidated summary, our view of what needs to be done to facilitate and accelerate the relevant research and its translation into patient-care practice. This exposes the importance of the digital collection, cataloguing and preservation of ocular images with support for easy but compliant access being established by SCONe and the opportunities that promises for critical elements of that research. We identify steps needed to realise SCONe's potential and suggest a strategy for accomplishing those steps. Ideas for further R&D lie within that strategy.

2 Interview results and analysis

OPS set out to identify the attitudes to changes in the use of ocular images among practicing optometrists, particularly with respect to changes required or enabled by SCONe. We designed interview scripts to reveal a range of expectations, issues and constraints. The scripts were revised by consultation with our expert advisors (listed in Appendix D page 56) and with experience. They were reshaped for interactions with ophthalmologists – see Appendices B (page 44 for optometrists) and C (page 53 for ophthalmologists). The thematic analysis was iterative and carefully reflected the transcripts of recorded interviews following the Braun and Clarke [2012] methodology. The outcome is revealed below. It confirmed some expectations, refuted others and revealed some unanticipated features.

2.1 Interview methodology and process

We interviewed 22 people (18 optometrists – 9 females – and 5 ophthalmologists – 4 females). We recruited initial interviewees through SCONe and extended the size and diversity of our sample through snowball techniques and recruitment through other channels.

We aimed to interview a broadly representative sample of optometrists that included both smaller independent practices and larger multiples as well as a range of geographical settings.

For the ophthalmologists we tried to select specialists in various fields (e.g., AMD, diabetic retinopathy, glaucoma) and from different locations. Table 1 lists those we interviewed.

[19] That will also require individual compliance with Caldicott procedures.

The interviews were conducted online through Microsoft Teams. With one exception (P19), only the interviewee and one interviewer were present. These were all recorded and professionally transcribed. The transcription introduced pseudonyms to protect identities. Security is provided by the University's Microsoft Sharepoint, OneDrive and Stream services and the transcription service 1st Class Secretarial Services, Gorebridge, Scotland.

The recruitment process was very slow at the beginning, because both optometrists and ophthalmologists are very busy in general, but also because of their unusually large workload catching up after the Covid-19 pandemic lockdown. With the help of SCONe optometrists and by snowballing we managed to develop a quite diverse sample of interviewees, including four of the multiple practice chains operating in Scotland[20]. Our initial focus was on Edinburgh and Lothians, reflecting a condition of the grant. When under-recruitment threatened, we decided to include interviewees from anywhere in Scotland. Though our sample over-represents local optometrists, we do not detect significant regional variations. In our conclusions we draw attention to actions and interpretations relevant to Edinburgh and the Lothians.

Table 1: Participants' details

Participant	Role	Location	Practice type
P1	optometrist	Glasgow & Clyde (city)	multiple
P2	optometrist	Ayrshire & Arran (town)	independent
P3	optometrist	Glasgow & Clyde (city)	independent
P4	optometrist	Tayside (town)	independent
P5	optometrist	Glasgow & Clyde (town)	independent
P6	optometrist	Lothian (rural)	independent
P7	optometrist	Lothian (city)	independent
P8	optometrist	Lothian (city)	independent
P10	optometrist	Glasgow & Clyde (town)	multiple
P13	optometrist	Borders (town)	independent
P15	optometrist	Glasgow & Clyde (city)	independent
P16	optometrist	Glasgow & Clyde (city)	independent
P18	optometrist	Glasgow & Clyde (city)	independent
P19	ophthalmologist	Lothian (city)	independent
P20	optometrist	Lothian (city)	independent
P21	ophthalmologist	Lothian (city)	independent
P22	ophthalmologist	Lothian (city)	independent
P23	ophthalmologist	Lothian (city)	independent
P24	optometrist	Lothian (city)	independent
P25	optometrist	Lothian (city)	multiple
P26	optometrist	Lothian (town)	independent
P27	ophthalmologist	Lothian (city)	independent
P28	optometrist	Highland (town)	multiple

For the optometrist interviews we designed a semi-structured interview schedule where questions were grouped into 4 categories: *data sharing*, *AI-enabled methods*, *research* with long-term benefits, and *education* related to data sharing and AI tools. We piloted this initial questionnaire and then, we refined it (see Appendix B page 44).

[20] There are 4 national multiples (Specsavers, Vision Express, Optical Express, Boots) and at least 2 regional chains (Duncan and Todd, Black & Lizars).

The questionnaire for ophthalmologists was designed after the first 8 optometrist interviews had been initially coded to understand which topics we needed to explore further. These led to the six categories in the questionnaire for the ophthalmologists: *opening questions*, *ophthalmology-optometry relationships*, *data sharing*, *AI-enabled methods* and tools, *research* with long-term benefits, and *education* related to data sharing and AI tools (see Appendix C page 53).

The interviews lasted between 30 and 60 minutes. Each interview was transcribed and anonymised. The analysis followed the Thematic Analysis method [Braun and Clarke 2012]. We conducted a total of around 900 minutes of interviews.

2.2 Interview and analysis results

The data analysis revealed six themes which encompass optometrists' and ophthalmologists' expectations and concerns regarding the implementation of the AI in ocular healthcare practice, including the Scottish national archive, as well as their suggestions. These themes are: *national [ocular-image] archive*, *AI [decision - support] tools*, *long-term benefits [exploiting the national archive]*, *education [training optometrists and ophthalmologists, educating patients]*, *optometry business,* and *service innovation*.

A map of the themes and sub-themes is presented in Figure 3.

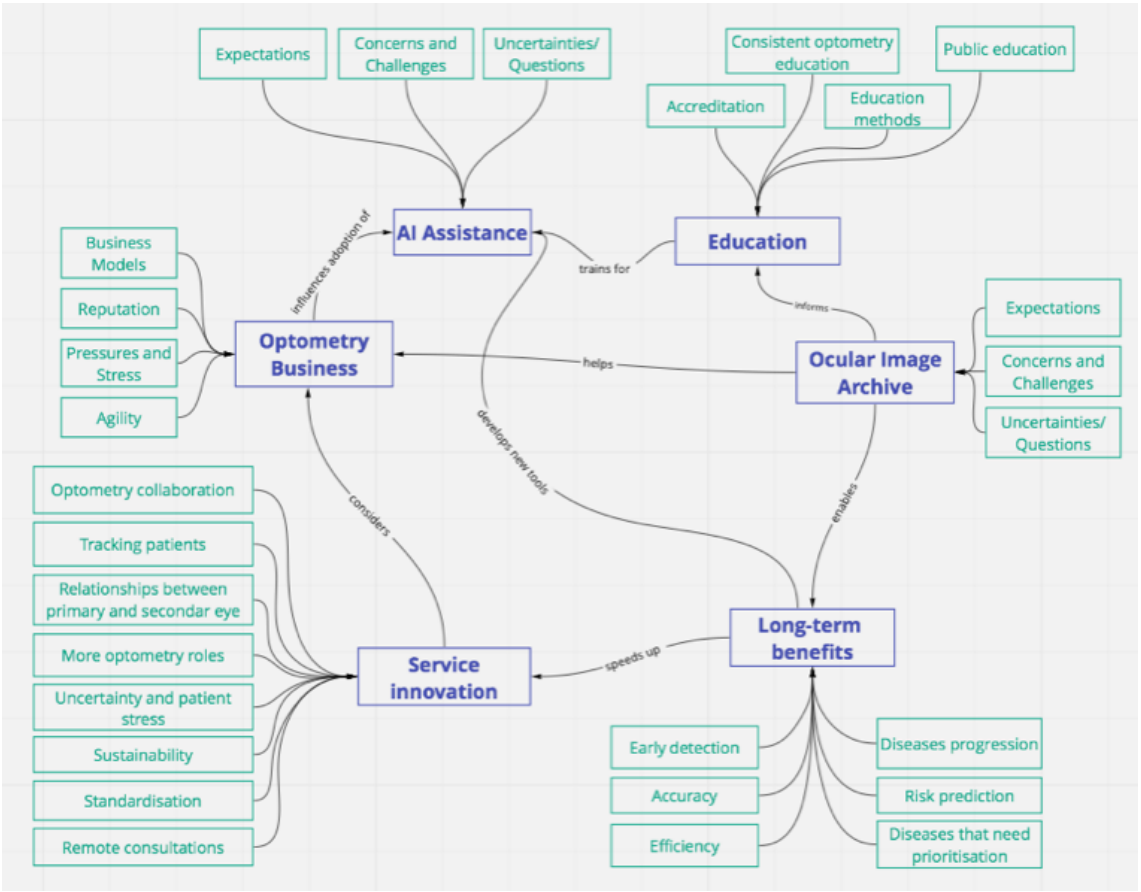

Figure 3: Thematic map showing six major themes and the sub-themes related to them. The links between themes reflect the reasons why, during interviews, the discussion migrated from one theme to another.

2.2.1 Ocular image archive

All participants were supportive of the creation of a collection of images and highlighted the benefits and concerns they perceived related to that[21]. Some optometrists hoped that a centralised data collection system would avoid ***duplication of work*** and offer a place where optometrists and ophthalmologists can access image data, as well as establishing a foundation that should enable improvements in patient care:

> *"I've always believed that there's far too much duplication of service across the health board. We got optometrists who've got multi modal devices doing retinal photography and OCTs. They're then sent to a centre to get a photograph taken by somebody who knows nothing about the back of the eye. And in the long run, it confuses patients, because they don't know who's looking after them, for their eyes, and I think that's wrong. Whereas if we have, like, a centralised service, and all this data is collected, it can only improve for the patient what's happening to them, and the health of their eyes." (P2)*

SCONe aims to create a sustainable national retinal image collection that is collaborative with research and teaching as its initial use. However, ***optometrists (14/18) hope that they will have access to this collection*** to use in their practice[22]:

> *"it would be nice to be able to access the actual data. And for us to use our clinical judgement in understanding and interpreting that data and how we care for our patients." (P18)*
>
> *"For myself and my colleagues, certainly the young colleagues, a database in which they could research some or put in an image and ask for a comparison or some information would be of real benefit. So for a sole practising optometrist or a young optometrist I think that's invaluable. I still think weekly I learn about eye conditions that I have to Google and check and cross reference. So an actual official database where you could go and look at images for comparative purposes would be really beneficial. As an optometrist rather than using Google as our current choice of reference, we'd know then that it was a reliable source and that it was exactly what it says and not what somebody has just thrown up on the internet." (P26)*

We note in passing that these pertain to the development of digital health records and revisit this in section 3.

A national archive can help reduce ***health inequalities*** (3/18):

> *"I suppose, it might be useful, because in some areas there might be more healthy patients, and in other areas there might be unhealthier patients. And the retinal images might help get some sort of understanding of that, so that, maybe that can be managed more. That might be something that could come out of it. And Scotland has got quite poor health inequalities" (P4)*
>
> *"And one of the challenges we have is, like, physical distance. So, you know, patients who are maybe hours away from a hospital or a flight away from a hospital and…it's very difficult sometimes making decisions when you can't…when there's a lot riding on it, whether it's a case of telling the patient that they have to fly in order to get this thing check[ed] out, you have to be really sure that what you're telling them to get a flight for is right." (P28)*

[21] Unsurprisingly, as most were recruited because they had signed up to the SCONe project creating that archive.

[22] This is not the role of SCONe. There is a different initiative separate from SCONe called 'OpenEyes' which is setting up a national eye health record archive which optometrists will have access to. https://www.nes.scot.nhs.uk/news/eyecare/

Having a rich collection of data could help discover some ***correlations between people's lifestyle and certain eye disease risk*** (3/18). One of the optometrists commented:

> *"One thing that interests me is that I think it could be interesting to show the differences in nutrition in different areas. […] Smoking is another one" (P7)*

It is recognised that, assuming that the necessary infrastructure is in place, it takes a considerable amount of time from the moment when research demonstrates the benefits of a new technique to its wide application in healthcare practices. One of the optometrists' expectations is that the creation of a national archive will ***reduce this time of 'translating' research into practice*** to 10 years (in contrast with the average of 17 years reported in Campbell *et al.* [2021]), and *"hopefully save some eyesight for people" (P3)*.

All the optometrists and ophthalmologists were happy regarding ***data sharing and use*** and were willing to see the SCONe research archive of image data applied in practice. They identified a series of benefits related to this archive beyond SCONe's research goals. Thus, some optometrists (3/18) hope that this will ***raise awareness about the quality of images*** and that will lead to some standardisation (see 2.2.6) of the ways of taking images and an improvement of image quality:

> *"I think just putting in standardised...standardising things across the board so the people who are taking the images know." (P10)*

Indeed, the optometrists drew the attention to the fact that once a collection of images (fundus and OCT) are being assembled the quality of these images may be an impediment for the research:

> *"For me the problem is a lot of images are pretty degraded effectively because the people you want to look at who are getting more problems tend to have poorer image qualities because of their media. I don't know about the quality of information you get and how you figure out that side of things and there is a lot of noise goes on. Effectively a lot of the time I don't really trust what I see on images that much because it just gets too degraded and I just have to look myself." (P16)*

Referring to the OCT images, an optometrist also mentioned:

> *"But I would just like to know that the quality of the images that are actually being used in the normative database are going to be good enough and who's going to filter them… we all have different OCT machines. So, you know, in different locations…I work as a locum often and in one practice they'll have a Topcon machine, in one practice they'll have NIDEK machine." (P28)*

Also, one of the optometrists' expectations is that the ***access to this collection (shared records) will be granted to primary and secondary care***[22]. This highlights an important implication, not initially foregrounded in discussions of this topic, that developing and using this collection will involve ***changes in the roles and relationships between community optometrists and secondary care clinicians***. Optometrist 28, noting that *"ophthalmologists and optometrists don't always work well together",* felt that image sharing could lead to better mutual understanding and communication and closer engagement between optometrist and ophthalmologists to provide better patient care (4/18):

> *"So a project like this could have a really good potential to make optometrists feel more inclusive, more part of the whole. I also think it would be a very useful way in which – again, without getting too much off the point – with linking primary and acute*

services so that you're out in the community, but we are part of the hospital project and yes, we engage with this data gathering which suddenly gives you the message, well, actually your opinion or your work – not necessarily opinion – your work is appreciated and valued." (P7)

The significance of image sharing was seen not only in terms of SCONe's research but also in opening up opportunities for integrated care delivery between primary and secondary care. It opened up valuable opportunities for optometrists to take on new responsibilities, since:

"hospitals are absolutely overwhelmed by the amount of patients and so the more tasks that can shifted from ophthalmologists to mid-level providers, the better. " (P28)

Tracking patients' data is particularly important given that patients may move between optometry practices. The national archive can provide access to the patient history (4/18, 1/5), especially since:

"patients move and patients' care providers move, and patients often attend optometry where they work as opposed to where they live" (P2)

"So I suppose it would be nice to be able to – rather than depending on a patient's word of mouth, like often patients are not the best in relaying accurate information about their past treatments and whatever else – it would be nice to be able to access the actual data." (P18)

Optometrists saw image-sharing technologies as potentially enabling them to access patient records held elsewhere. Such service integration goes well beyond what the SCONe research project envisages[22] – and would involve significant additional technical, information and clinical-governance challenges.

One of the frustrations they expressed is that ***a lot of data they collect may not be used*** (2/18)

"don't send their files and photographs and OCTs to the hospital, because it's difficult for them to transfer them on to SCI Gateway to get there in the first place. But equally so, the doctors don't always look at them, so that's why they don't do it." (P5).

In contrast, all the interviewed ophthalmologists mentioned they look at the files sent by optometrists and these are useful for them to decide how quickly to intervene:

"Yes, most of the time they're actually useful in deciding that I don't need to see the patient – so that's good." (P23 ophthalmologist)

However, ophthalmologists do not always receive good quality images from optometrists:

"They vary. If it's just fundus images they're usually okay […] The OCT images that they sometimes send are a little bit more variable because the machines seems to vary, so you get some that are almost useless really because they're not comparable with the OCTs that we'd be doing here.[…] I don't usually take plain photographs again because I'm actually looking at the patient, but I do sometimes and I always repeat the OCTs." (P23 ophthalmologist)

The reason for the low quality of the images sent by optometrists may be conditions such as cataracts impeding the camera's view. Differences between devices used by optometrists and those used in ophthalmology centres may prevent image inspection:

"everyone in Scotland would need to be able to access it [the national archive] and would need to be able to compare the images that they take on no matter which

machine it is to this database. And, you know, each machine takes a slightly different type of scan" (P28)

OCT-image quality is also affected by limitations in the transfer process:

"And the reason for that, is the opticians will give a single, a static image, whereas our images here we can play as a video so we can get a lot of in-depth information about a segment of the retina. So, therefore, I repeat retinal images in my practice. (P22)

When the time between the referral and appointment with an ophthalmologist is long (a few weeks or months) then the image must be taken again.

"we need to know whether it's the same pathology, whether it's got progressed…" (P27).

Two optometrists were worried that the ***data image collection could be used against them*** to investigate whether or not their decisions were right. Particularly, one optometrist highlighted that, their decision could quite likely be different from one made solely based on image data (OCT or photographs) -- without the information about the patient history and the details offered by a physical investigation of the patient:

"if the OCT and the photograph went to somewhere else and someone else made a decision on that and they disagreed with you, would that potentially put me in a position where I could be investigated or … but, you know, the person that was looking at them after me didn't have the whole data because they didn't have the patient history, they didn't know that patient, they didn't physically look in their eyes. So I would be a little bit concerned that I would … you know, someone would be, sort of, looking over my shoulder and deciding whether I had made the right decision or not, whereas they didn't have all the data that I had available." (P28)

Regarding the patients' attitude toward data sharing most of the optometrists (17/18) think they would be positive, provided they are assured that their data is protected. Some optometrists expect that the patient attitude would vary and that *"patients that are a little bit more elderly are somewhat maybe resistant to sharing their data because they want to know where it has gone and who has their details" (P15).* However, all ***optometrists expect that the majority of patients would be willing to share their data***, if they are reassured that it is properly managed and they were informed about the benefits of the image collection. Optometrists were however concerned that they might need to ***spend additional time in longer conversations*** with patients to explain to them how their data (6/18) is used and protected.

"I think these days patients want more explanation and they want reasons given and they expect that from Data Protection Act, which to me ends up just taking a lot more time out of my day" (P28)

Practical/technical issues regarding the requirements around taking and uploading the images into the image archive, as well as the ***time needed to take and upload images*** were also concerns expressed by some of the optometrists (8/18):

"Patient file and things become difficult, both in terms of consent, patient information, and then even if we want to anonymise patient information, which is obviously worthwhile, that then becomes, I would say, burdensome on the practice's side." (P8)

"That's the biggest challenge, it's always…it's all about how do we get these images on to a platform that's transferred easily, and that's not too time consuming. Because I know there's optometrists that don't send their files and photographs and OCTs to the

hospital, because it's difficult for them to transfer them on to SCI Gateway to get there in the first place." (P5)

Current technology limitations and the need for new equipment and software which implies extra-expenses was another concern expressed by optometrists (5/18) (that led the discussion to standardisation which is presented in 2.2.6).

"Is everyone going to have to have the same computers? There might be a technology issue and a standard that, you know...and can you...there are so many different types of devices, how easy is it to tag it on to...and you know…different manufacturers, different proprietary software […] I think that is going to be a challenge getting things to work for everyone. I don't think…I think people would be annoyed if there was a development and then that became very limited to who could get that technology. I think it would have to be available…it is going to be...you know, community based means everyone has got to be able to get access to it if they want but if it becomes very, well you need this system and it only works with that and you need to invest a lot of money to get it done, then that would create a bit of friction I think." (P16)

Various suggestions were made to ease data sharing and use. To avoid technical and practical issues around data sharing, the whole process of sharing data should be quick and easy, and ***processes should be automated*** where possible (8/18). For example, images could be automatically uploaded into the databank.

Optometrists were concerned that they would need to spend much time explaining SCONe and how information would be governed and used to their patients. Thus, they suggested that the project should be well advertised nationally, so patients can acquire good understanding of what is happening with their data and gain trust that use of their information is legal, fair, acceptable and safe. More information about the SCONe project should be available both online (e.g. on websites) and in physical format to be available for the patients (e.g. leaflets).

Since trust can easily become fragile if (too) many organisations are involved, having NHS as a 'guarantor' could reduce this danger:

"If it was an NHS-driven and labelled product, they would have more trust. … I assume it's an NHS initiative per se, that it's for the benefit of the patient and it's not a corporate data gathering sort of like process. So that they didn't feel that I was responsible for any sort of breach or corruption of their data ... I think there needs to be a lot of thought put into how it can be implemented, because it will fall flat on its face if it doesn't have buy-in from organisations, because you're dealing with not the NHS which is used to" (P25)

Some interviewees (5/18) felt they did not have enough information about SCONe:

"At the moment, yes. I don't think we maybe know enough or too much about it. But I think that is something definitely going forward that we could maybe raise awareness in, in what SCONe is doing and things like that. I think if that was the case and the information was more readily available or was made compulsory across the board, I think that would certainly make things much easier." (P10)

Several interviewees raised questions about SCONe's plans which are summarised later at the end of 2.2.6.

2.2.2 AI assistance

All optometrists were aware of the multiple benefits of AI tools and hence were happy to adopt and use them. The ***AI tools were seen as augmenting the skills*** of community optometrists, and empowering them to make better decisions and be more confident (14/18):

"I would feel it was an affirmation probably of what I was doing, or even a confirmation of what I was doing." (P5)

Among the anticipated benefits from using AI tools the most prominent were: ***getting in touch with more patients, having more treatment options*** and ***more guidance based on image data, reducing the effects of differences in optometrists' experience***, thereby improving patient care. ***Workload may be reduced*** since the burden of reviewing an increased number of images can be taken from optometrists:

"*I would hope it would, one of the big things now is with ever-increasing imaging you've got an ever-increasing review burden of reviewing that imaging, and if AI allows you to do that at a more efficient pace and a more accurate pace" (P2)*

Optometrists felt that they should ***retain control and that the ultimate decision remains their responsibility*** (10/18)**:**

"I think you have to take the human factors into account and base it on all your observations not just what the technology is telling you." (P15)

Some optometrists (6/18) expressed concerns that their colleagues might ***fail to develop clinical decision-making skills*** (particularly optometrists at the beginning of their career) or that clinical skills might fade amongst those who become too dependent on the new technology, coupled with a risk of misinterpreting the "*results in the AI*".

"I think it's important that it may be something that if it's brought in too early in somebody's training as a clinician, then what [they may] actually fail to develop their own clinical decision-making skills." (P18)

"So, I think that we'd have to be very clear that whoever's interpreting the results in the AI tool understands how to interpret the results, as well as preventing skill fade from clinicians that are used to interpreting these images just now." (P2)

There were a number of other concerns and challenges that the optometrists highlighted. One of them is related to the ***additional workload and time needed to be trained for using the AI tools*** (8/18), which may not be sufficiently well rewarded:

"People's working days are very busy and unfortunately the way the GOS contract is structured clinical stuff isn't [the] thing that pays the bills. So, something that's additional clinical that's going to generate workload but not potentially generate benefit I think is going to be a tough sell." (P2)

With the adoption of the new AI tools, optometrists realised that they will inherently ***take on new responsibilities.*** Most interviewees (17/18) were enthusiastic about the new possibilities and the fact that the AI tools will allow them to improve patient care, thereby increasing their prestige. However, they highlighted that this required additional skills and a willingness to engage with professional development which might otherwise create a rift in the optometry community:

"There are some practitioners, although I should point out that I'm talking about a small minority of practitioners (that typically qualified many years ago) who feel that, at the time they qualified, they were trained to examine eyes and provide optical corrections and they don't like this whole shift …" (P6)

On the other hand, the idea that optometrists are expected to take more responsibilities (1/18) pose difficulties if they don't have the necessary equipment and necessary training:

"There are definitely some practitioners who feel like it's sort of racing ahead without them necessarily having the appropriate training, so there's that concern, whereas I sit on the other side: I'm an independent prescriber and I've always tried to push myself

forward educationally, and I'm more interested in the healthcare side of the profession than the selling glasses/retail side of it obviously." (P6)

In addition, being able to identify ***conditions for which they are not able to provide advice*** (2/18) and management may make optometrists anxious: *"you know, apart from identifying conditions that we can't provide advice and management for. That's one concern." (P4)*

Some optometrists are concerned about the impact of AI and the reliance on automatic diagnostic tools on their ***personal contact with their patients*** to the degree that ***they fear to be replaced by machines*** (5/18):

" I think there is a risk of reducing the respect and the qualifications and the ability of the optometrist to a certain extent, if it is used to replace certain parts of a test rather than aid." (P10)

"Yes, I have concerns that I won't be needed. I think that's the big thing, you know, like, you'll be replaced by a machine." (P3)

This fear was also strongly emphasised by one of the ophthalmologists, too:

"So that may be the world that everyone wants and that's the way we're headed. AI driven yeah. We'll have AI produced glasses, we'll have AI produced images, refer to hospital, don't refer. At the hospital, the patient turns up, the AI says, but health need your injection. You could dispense with everyone. We're laughing, but that is the potential reality in 50 to 100 years' time, most people won't need to…there won't be any jobs because AI will have…and I think that there are big considerations to take into account here of AI. Also the whole issue regarding, well maybe you want to see an empathetic optometrist. Maybe you want to see an empathetic doctor. Well we know that AI can produce empathy artificially, so maybe you can have empathetic robots performing all our roles in life." (P21)

Current technology limitations and procurement issues *(e. g., quality of equipment and costs)* ***related to acquiring new equipment*** were brought into discussion by few optometrists (7/18):

"I think people would be annoyed if there was a development and then that became very limited to who could get that technology. I think it would have to be available…it is going to be...you know, community based means everyone has got to be able to get access to it if they want but if it becomes very, well you need this system and it only works with that and you need to invest a lot of money to get it done, then that would create a bit of friction I think." (P16)

One of the concerns around the technology limitations was related to image quality. The fact that optometrists use various devices, some of them quite old, leads to low quality images:

"Again, one of the problems at the moment is that there are a lot of 1st generation cameras – talking about fundus photography – on the go, and sometimes they can be a little bit awkward to use, perhaps. And again, the quality of the image becomes a factor." (P7)

One optometrist expressed their hope that AI could help improve image quality in patients with hazy media[23]:

"we might be sharing data that is below quality, but it's beyond our control. Because we can't make a hazy image less hazy, if you see what I mean. I mean, maybe artificial intelligence will be able to get around that, to some extent..." (P4)

[23] Conditions such as cataracts prevent sharp images; AI algorithms that could help recover useful information from such images are infeasible at present as there is too high a risk of incorrect conclusions.

2.2.3 Long-term benefits

Respondents identified a range of longer-term benefits, including ***early detection*** (18/18), increasing ***accuracy*** (10/18) and ***efficiency*** (4/18), as well as better ***disease progress*** (8/18) and ***risk prediction*** (7/18).

Early detection is obviously helpful in saving eyesight, particularly in diseases like AMD, or glaucoma where early diagnosis and treatment have enormous benefits for patient health outcomes:

> *"And hopefully I guess maybe catch things before it got to a more, kind of, progressive stage where it was more devastating to sight as well." (P13)*
>
> *"So obviously anything that we can do to detect things at an earlier stage, you then potentially can prevent sight loss for our patients, which is ultimately our goal, is try and keep our patients seeing as well as they can for as long as they can." (P1)*
>
> *"You would hope, a better quality of eye examination if again you're able to identify and pick up disease at an earlier stage, so in terms of patients, less sight loss, particularly for macular degeneration and diabetic retinopathy, if you can intervene at an earlier stage obviously." (P6)*

Optometrists may need to see patients several times e.g., when they are uncertain regarding the disease. Therefore, if AI technologies are available to help them make a more ***accurate*** decision, particularly with subtle signs that are not apparent during physical examination or through imaging technology, or when the signs are not conclusive, this can help reduce optometrists' workload, achieve earlier diagnoses and increase their efficiency:

> *"So, often we'll see patients a lot for follow-up appointments just because we're uncertain. But if these AI technologies allow us to make – even in those grey or uncertain patient situations – a better or a quicker judgement call, then that would be handy." (P18)*
>
> *"I think if you have good information, well pointers, to help people and it helps you in a busy time. Currently you acquire images, you analyse them. I always compare them with my oldest images and see what I can see. [I] try to get information out of them. I suppose you are doing a kind of pattern recognition yourself. You always scan things, look at it. You are trying to do what a computer would do but obviously we are imperfect." (P16)*
>
> *"it's the hidden things, the occult things, the subtle things that you might not even pick up by eye." (P7)*

Besides its benefits for patient care through the 'speed of diagnosis' and the opportunity to see more patients in shorter time, an increase in ***efficiency*** can reduce patient waiting times and stress:

> *"It needs to be as close to real time as possible so that it can be, or in a very clear way of generating a result that doesn't have the anxiety of waiting on an envelope coming through the door or an email, as much as possible." (P2)*

Support for managing ***disease progression*** has been emphasised as one of the optometrists' expectations from the long-term research:

> *"You know, most of the OCTs have progression analysis tools on them, and so therefore any changes are there." (P5)*

However, optometrists expect also to be in a better position to ***predict risks*** – a key goal of SCONe:

> *"Then I think we would be in a better position to predict patients at risk. Rather than monitor patients who already are showing signs of disease, if we were to have a*

database of all patients in Scotland, their retinal images, it might be easier to predict and follow the patients through. It may be easier to predict patients at risk of developing certain conditions." (P10)

The diseases that need to be prioritised in the future research mentioned by both optometrists and ophthalmologists include AMD (5/5) and glaucoma (4/5), which seems to require *"80% [of] NHS [ophthalmology] work in Scotland" (P27*, ophthalmologist), as well as diabetic retinopathy (1/5) – as noted above in Section 1 page 7, there is already an automated service using AI for diabetic retinopathy in Scotland.

2.2.4 Education

Sharing image data and the use of AI tools are new for both ophthalmologists and optometrists. Therefore, education is needed to prepare them to exploit image sharing and AI tools in a reliable way.

Two optometrists suggested developing ***CET-accredited educational resources*** about AI and its role in eye care to encourage AI-related education[24]:

"I suppose you'd want some sort of accreditation linked to it, or certainly CET, which is what we talk about in the profession. We get CET points for education. There are some optometrists who are definitely motivated by CET when it comes to education, as you need to get so many points a year to stay registered, so you'd want to link it to CET where possible." (P6)

The idea of a ***consistent optometry education***, to ensure national standards of education and hence consistency across optometrists came out from 5 out of 18 optometrists:

"All I would really suggest is I think it would be good if, perhaps in conjunction with Optometry Scotland and NES [NHS Education for Scotland], if all optometrists had to do mandatory training as part of their CPD. If this was rolled out nationwide and if it was made part of our mandatory training, then we would all be starting on the same page." (P15)

Various ***methods of delivering training*** were suggested, with the purpose of integrating the education in the busy schedules of optometrists, but also to make the training more efficient and effective. Thus, to be efficient, and accommodate optometrists' workloads without perturbing required working practice, P5 proposed:

"In terms of the actual education itself, I suppose ideally a lot of optometrists don't have a lot of time, so you'd want it to be delivered in the most accessible way for optometrists, so they can perhaps access it during their lunch hours or not having to sort of turn up and give up a day of their time, because time's quite precious, so potentially something that's either sort of bite-sized chunks or that you can sort of dip in and out of, some sort of e-learning module or something like that, so that you could potentially finish it over a period of time." (P5)

Other optometrists proposed various forms of online teaching, including online platforms and FAQs:

"There are conferences, there are online platforms we can go to. You could have a site. If it was just an explanation of things it is easy enough to give a lecture, and FAQs and some examples and things like that, I think that is a good start." (P16)

More participants proposed real scenario-based workshops:

"I think some practical interactive workshop *based [on] real scenarios is always useful." (P2)*

[24] Optometrists working with SCONe are working towards this goal.

Shadowing a *"more skilled individual"* over a number of days was also proposed, with opportunities to apply the newly acquired skill, then to reflect on the results and challenges, review and reapply.

> *"I think what has to be understood is that I think it has to be interactive. Maybe watching a more skilled individual…observing, almost like 'Teach and Treat' sessions. So if there are clinicians that are using this data, if they could demonstrate…sitting in with them for five days and watching them use it and then asking questions as it goes along …. So maybe initially observing a clinician who's trained in it already and then for the latter part, the trained person observes you using the same technology to see if you've understood its application." (P18)*

Patient education is also crucial to the success of the data sharing and AI within the ocular health domain [Campbell *et al.* 2021]. This should be extended to ***public education*** to help those who support the patients. Time to discuss these new approaches, and the availability of information in various formats (e.g., on the paper or online) in a simple and concise language, would help ease the adoption.

> *"perhaps a website that they could access, although a lot of patients are elderly and aren't able to access the internet necessarily, so again you're back to accessibility issues of having the information available in different formats, so perhaps a paper format for patients who aren't technology savvy, and then perhaps websites for those who are. You'd certainly need something that makes the optometrist's life easier in terms of cascading the information to patients, … some sort of information pack they can just hand out to the patient which takes them no effort or time to be involved in" (P6)*

Steering groups involving optometrists, ophthalmologists, technical specialists, and patients were suggested to raise patients' awareness of the benefits of AI, but also to discuss their concerns and challenges related to that:

> *"I'm just wondering if you could have…when you're coming to design all of this, and probably this is already happening, but you could have a steering group with optometrists, ophthalmologists, tech guys, patients represented, so that you can hear their views, but maybe you're doing that already. Is that a plan? To do this with some patients as well, hear their views on it?…" (P6)*

2.2.5 Optometry business

It is important to recognise the ***commercial pressures on community optometrists*** – who work in a competitive market of small private enterprises and larger chains – that make most of their income from retail business – prescribing spectacle frames and lenses (12/18, 3/5):

> *"I think sometimes optometry's a strange one [community] because it is, you know, sort of 90 per cent clinical but there is a commercial aspect to it and we are in competition with each other." (P3)*

> *"Also we need to recognise optometrists' role as retailers" (P20)*

Three optometrists expressed concerns that the additional cost of acquiring equipment and training in its use, and the time spent on community referrals could create financial pressures on their business:

> *"But a lot of practices would be apprehensive, or just think, look, it's not worth the hassle, for them to be involved in the project." (P8)*

> *"People's working days are very busy and unfortunately the way the GOS contract is structured clinical stuff isn't this thing that pays the bills. So, something that's additional clinical that's going to generate workload, but not potentially generate benefit I think is going to be a tough sell." (P2)*

However, some optometrists are keen on learning and applying new things and being up to date to offer the best patient care:

> *"There may be some practitioners who won't want to opt into it, due to time constraints and because they're more focussed on the retail side of their business. Sadly, because of the way the system is structured, selling glasses is where practitioners make their biggest profit and as business owners, they may feel they need to maximise that. Most practitioners are of course far more focussed on the healthcare side of the profession." (P6)*

> *"I think it's more a question of service, you know, and pride in your profession, and providing the best standard of care that you can provide." (P19, ophthalmologist)*

Those from independent practices felt they were able to exercise more choice over the allocation of effort between their retail/prescribing and an expanded health professional role:

> *"Independent practices work very differently than, for example, multiple practices.[…] So, in my current practice, because it's my practice, I don't feel time pressured, because if I'm going to run over, if I need more time, I take more time, there's no one hounding me to say, next patient is here, next patient is here. Next patient might be there, I'll just tell them, look I'm running behind, this patient needs more time. I have the luxury of that, the majority of optometrists, especially who work for multiples, do not." (P8)*

> *Well I think, this is a huge sweeping statement, but I only know from employing other optometrists from the multiples, that they get much less time. They have targets to meet, they have figures to reach, they have sales to match. It's a very different environment. They're about volume, because they do everything so cheaply, everything has to be high volume and less time. Whereas [as] an independent, you want to provide the time because you want to look after your patients and offer a superior service, but then you have to charge more because it takes more time. Yeah, the multiples do high volume turnover, less time. We do more time, but the products have to be more expensive to pay for the time because you're perceived as you can't charge for the eye exam. (P26)*

If these competing incentives shaping the allocation of effort create a divergence in optometry business strategies between an expanded health professional and retail role this may lead to ***a rift in the optometry community*** - some optometrists seeing themselves as medical professionals and thereby more interested in AI and adopting new screening technologies, while others would be more focused on selling glasses[25]:

> *"I mean, would it be a sort of opt in or opt out? Would some practices take on these new pieces of equipment with new AI technology, whereas others are then left behind, and does that then create a split in the market for optometrists, where some are seen as being more advanced than others? We've already got that a little bit with independent prescribing. Some optometrists have gone on and undertaken an extra qualification [Independent Prescribing diploma], which allows them to write prescriptions and diagnose and treat eye conditions, and others haven't, and we've already got a bit of a split. Should practitioners be getting paid more because they're doing extra or more advanced work? I could potentially see that creating a bit of a rift. (P6)*

> *"But it depends, also, but not everyone will want that. So, optometrists should be, you know, because some are more commercially minded, and they may want to do, make money and work with the private sector, and do refractive surgery, and other things. But I think there is scope for everyone, really, basically, and I think there should be an*

[25] This is of course a vital service in ocular healthcare, as a great many people need refractive correction.

effort to try and work together, basically, because that would be the ideal situation. And the optometrists would still be in a very good commercial position, and economic, because glasses are a good business, really." (P19, ophthalmologist)

Such a *"two tier business model"* might be reinforced by patient attitudes with *"people who don't believe that there's a problem with their eyes and they just want to go and get glasses" (P28)*. Another optometrist explained how ***difficult it is to keep the balance*** between the two main sides of their practice, providing healthcare and selling glasses:

So it's a hard one because you have to sell glasses to keep a business. But a lot of the secondary care stuff doesn't pay for your time. So you don't get paid enough from the NHS to provide these services to be able to do that solely. So when you're managing your diary you have to consider options on who's in, how many points do you allocate to health? How many do you allocate to children? How many do you allocate to somebody likely to buy glasses? It's a very tricky balance to pull off. So in England, where the eye test is not free, most of them are going private. So as an optometrist they would separate and just go private and don't do any NHS work, which is very much the trend currently, especially after COVID. (P26)

The optometrist P24 explained further the struggle they face in differentiating between the two sides within their own practice, but also the fact that this difference is difficult for other people to make:

"So there are two elements to optometry and it's very blurred lines and it's very… And as a practice owner that's hard to differentiate between being a healthcare provider and providing your eyewear[26]. And almost you see optometry separating, you see it separating into an eyewear versus a clinical service. So it's viewed as retail by some and healthcare by others. That's a very hard battle that the optometrist has to fight." (P24)

These choices are affected by public policy and funding arrangements. While one optometrist explained that: *"The contract with the NHS that we have in Scotland empowers us more, pays us more, pays us to do some monitoring of conditions" (P24)*, optometrist P25 noted that although they are doing more tests and interpretation – and also need to spend time explaining these to the patient, *"the NHS fee hasn't changed very much at all"*.

However, the interviewed optometrists (7/18) recognise that adopting new technologies could help increase their ***efficiency*** (see more patients) as explained above in "Long-term research" and decrease the ***workload and stress*** which in the long term may pay off:

"I suppose that has to be a discussion where do we have the facilities and the capacity to do this kind of extra work. Because it would be extra work for us, if we are keeping patients or trying to keep them out of secondary eye care and keeping them away from the hospital if we are holding onto them and reviewing them and managing them ourselves. I suppose it is just a capacity issue and whether or not community practices would be happy to engage with that, is another thing as well, because I suppose there is a monetary element to it." (P15)

While one optometrist was concerned about the risk that AI tools could reduce the *"professional integrity of optometrists"* (1/18), if they are used to replace *"certain parts of a test"*, many optometrists consider that using the new technologies would ***increase their reputation*** (7/18) and help them visibly ***stay up to date*** (1/18):

[26] We note that providing refractive correction is a critical and invaluable aspect of healthcare and a sight-preserving service for many provided by optometrists.

"If you're explaining to a patient that you're using artificial intelligence, the patient would be very impressed with that, probably, and probably, in a lot of cases, quite happy to see that their optometrist is using up to date methods, and software." (P4)

"And I think patients appreciate that, and in signing up to it and being involved, then I think it does let patients know that, you know, how seriously you take the medical aspect of their eye care. So I think all of those things, kind of, help; it just gives the practice a kind of a standing within the medical community, which would help." (P3)

2.2.6 Service innovation

A series of directions for service innovation were revealed, related to: ***optometry collaboration and learning, tracking patients, relationships between primary and secondary eye care, more optometry roles, uncertainty and patient stress, sustainability, standardisation*** and ***remote consultations.***

Optometrists feel that they work in isolation, but quite often ***they need to relate to other colleagues and consult them***:

"And one of our problems in optometry and one of the things this project would potentially help with is that we generally work in isolation … which isn't really ideal… this would help with developing the whole idea of collaborative optometry." (P6)

So, although we are part of the NHS in some ways, we are also on the outside of the NHS. We're not like a GP who has lots of NHS services going around and lots of NHS people in their life. It's not like that for optometrists; we still sit slightly on the very edge of the NHS in terms of our interaction with other professionals. So, I guess, we're not used to being a part of bigger things like this. (P24)

Even more, optometrists (12/18) think that the SCONe project, with its national ocular-image archive, could open the door to the creation of a community where optometrists can learn from each other and collectively manage patients:

"We can learn from other people's treatment management plans and things like that. And it just means that we can enhance a collective learning and collective management of patients." (P18)

"Having community opticians help in disease management is the next best thing" (P20)

Some optometrists think that having access to the collection of data can enhance collective learning and management of patients (4/18):

"We can learn from other people's treatment management plans and things like that. And it just means that we can enhance a collective learning and collective management of patients." (P18)

More data will be beneficial for learning and education. Optometrist P6 explained:

"It would be very useful if educational providers … could have access to a retinal bank of images/data. These would be useful to help develop case studies and other material for educational purposes. The hospital departments would also find access to such information useful when training their junior medics etc." (P6)

Another optometrist remarked:

"I think there's very little point in doing a project like this in a regional or a health board basis; it really should be national." (P2)

A change in ***relationships between optometrists and ophthalmologists*** is required (10/18). Optometrists hope to improve the communication between them as do ophthalmologists as at present it is not as good as it should be:

"I think there has been a lot of work done on improving relationships between hospital and optometry, so community practice and secondary care, and there is definitely a bit of a barrier between the two." (P10)

" being able to deal with the communication and the…like, the problem in cohesiveness between those two levels of care would need to be overcome before I think technology would be as successful as it could be." (P28)

Some optometrists think that they need to have better communication with the ophthalmologists and to get more information about what happens to their patients:

"I think if SCONe could help break that barrier, make it much easier to share information, then that would be a big improvement for optometrists and also for patients, because when they come back, we have not always got the information of their previous hospital appointment or from their previous referral and things like that, so I think definitely that would be useful to share. If a patient has been discharged, we are doing a lot more community discharge care of stable patients, for example, glaucoma. It would be really useful if we could have their discharge photographs and images as well so we have got something to get a baseline as what they were when they were discharged, to monitor and compare as time goes on. I think that would be really useful." (P10)

Though all the interviewed ophthalmologists stated they always send a letter to the optometrist who referred a patient, there are however exceptions when they hand the letter to the patient:

"Normally, you do copy the letter to the referring optometrist, so, the person who did refer. But, so, what I do is I ask the patient if they're seeing the same optician, and if they're not, then I send a copy of the letter to themselves, so then they can take it onto their own optician, to the new one." (P19, ophthalmologist)

However, ophthalmologists do not know whether the patient takes this letter if they transfer to a new optometrist. They felt this could create problems but not enough is known about this:

"I don't know how big a problem that is. That would be interesting to find out, you know, how. Because I think a lot of people do continue to go and see the same optometrist, unless they've had a bad experience, or they want to shop around, or they feel that, you know, they're not being treated fairly, or something. But it would be interesting to know how loyal the people are to their own optometrists, and how much of a problem that really is, really." (P19, ophthalmologist)

Continuity of care is most readily assured if the patient stays with the same optometrist. However, the patient should have the freedom of choice about how this might be delivered:

"Particularly, I think that for, if you're going to implement programmes whereby you're going to have shared care with optometry, and they're going to see, for example, a stable glaucoma, let's say, a stable macular degeneration patient, you really need to make sure that they understand, and they're followed up. But of course, you also want to make sure that the patients also have a choice, you know, if they fall out, or they're not happy, that they also have a choice, you know. " (P19, ophthalmologist)

In the context of people moving between optometry practices, some optometrists wondered whether a national archive might help ***tracking the patient*** in the same way that happens with the medical records when patients transfer between GPs or healthcare regions (3/18) – OpenEyes, a contemporary independent initiative is addressing this need for Scotland[22]. Optometrist P18 remarked:

"if it is something that is put into that context for a patient then they understand that it is a means by which they have more consistent and continuous care. You know, if they are swapping practices and whatever else it means that information isn't lost as a

result. Or if there were concerns at the last appointment it's continued [to be addressed] and it can be accessed and understood by the new optometrist. (P18)"

Hospital based ophthalmologists however felt that sharing data of a patient between optometrists and ophthalmologists/other optometrists might better be achieved through ongoing plans to develop electronic patient records:

"I think hopefully, well, we're supposed to be going to a digital or an electronic patient record with images, so if that was shared with optometrists they might be able to learn from that." (P23, ophthalmologist)

To reduce the burden on secondary care and to get good quality images, one of the ophthalmologists proposed to create hubs where patients can be sent for images:

"It would be very useful to have imaging hubs where imaging equipment can be standardised and similar to the ones used in NHS Ophthalmology Departments, and these produce high resolution photographs which are essential for safe management of patients. We comprehend that the type of resolution we are wanting wrt image acquisition is virtually impossible for all the optometric practices to have." (P22, ophthalmologist)

A gap exists in the communication between optometrists and GPs. Optometrists often refer a patient to a GP, but they never get the GP's feedback:

"I suppose we're only really part of the, one part of the health care system, and we don't have good links with GPs, in terms of, we only write to them, you know ... The reason why I say that is, you know, for instance, one of the benefits might be, the AI might say that the patient is at risk of cardiovascular problems, so then I refer them to the GP. Now, we then don't get feedback from GPs, so it wouldn't be easy for me to know what actually happened with that patient. We would have to set up some sort of way of almost getting feedback from the patient, to know whether it had been useful for them to have had that information, and for that referral to have taken place." (P4)

There are cases when there is no time to refer the patient via an intermediary like a GP, so community monitoring and bypassing the GP would work better[27]:

"They [GPs] have almost agreed to being bypassed. GPs are busy enough – and they understand the need to defer to community opticians and eye hospitals" (P20)

The idea of jointly developing treatment plans was emphasised by both optometrists (5/18) and ophthalmologists (2/5). For example, P20, an optometrist, has been working with ophthalmologists in hospitals. They set up a clinic beside the eye pavilion[28] where community optometrists could see patients in the presence of ophthalmic specialists if needed. An ophthalmologist also commented:

"You know what works well – for example in a macula clinic it's not just about assessment of the macula, it's a lot more as most patients might have other co morbidities such as diabetes, cataract and glaucoma. What I have historically found is if we can have a small group of opticians in the hospital who work and train with us and use the same equipment, then there is a degree of quality control and they understand and deliver the preferred practice patterns. Also they can liaise with us very easily with queries. So I'm very for hospital optometrists working in our teams. And I feel that I can support the training and development and progress of these small cohorts very well rather than communicating with multiple community opticians." (P22, ophthalmologist)

To improve the ***relationships between primary and secondary care***, but also to train them for taking more roles, the ophthalmologists (2/5) also suggested having more optometrists visiting hospitals:

[27] Referral in Scotland is direct from optometry primary care to ophthalmology secondary care, but it used to go via GPs.

[28] Princess Alexandra Eye Pavilion, the ophthalmology specialists' location in Edinburgh.

"I think if the opticians came into the hospital more frequently for either updates or we had more communication between us" (P23, ophthalmologist)

Another ophthalmologist proposed a direct link between optometrists and ophthalmologists:

"even if they are managing these patients, there has to be a link where if they feel that, you know what, I can manage, but it's beyond my capacity now, there should be a link where they can directly contact the consultant and seek advice, and that's what's happening with these NESGAT opticians at the moment in Edinburgh. So they see patients, if there's anything they refer the patient back to us and then be managed if they want any opinion, so there has to be this direct link as well between the two groups." (P27, ophthalmologist)

Optometrists (11/18) and ophthalmologists (4/5) both highlighted the scope to ***expand the role of optometrists*** as a result of adopting new technologies:

"Hopefully, it will enable us to provide a better service for patients. There might be times where you do not have to refer into hospitals and you will be able to manage someone locally." (P15)

The optometrist P28 believes that "*a huge amount of optometrists are willing to take on more responsibility*" and that in the future the optometrist profession will diversify into a range of professions:

"So I think we need to start having some kind of differentiation in the hierarchy in eye care. And not just optometrists and ophthalmologists but a continuum between the two."(P28)

This change of services can be a solution that reduces the burden on secondary care:

"Sometimes, the hospital will follow up and tell community opticians to monitor the condition" (P20)

"Glaucoma definitely, we're hoping that majority of our stable patients can be seen in the community, that'll really help us, and I think it's about good 60 per cent of patients have stable glaucoma who are still in the secondary care which is in the hospital set-up. If these can go into community care, that'll be ideal, yeah." (P27, ophthalmologist)

However, this expansion of roles should be carefully analysed and balanced (4/18, 2/5). For example, an optometrist may not receive adequate financial rewards for their additional work:

"So you find that optometrists are sitting there going, sorry, I'm now checking blood pressure on some patients, I'm doing OCT, I'm doing glaucoma assessments, I'm doing low vision assessments, and all of this is to be done for much the same costs that I got as a sight test which didn't pay me enough in the first place, that's why I had to sell glasses. And because you're now doing that, you're not working extra hours in the day, you're not open till eight o'clock at night, so you're seeing less people who are buying glasses and therefore you're making less money. So the idea behind it is that we're moving more professionally and we're moving into a better, more rewarding profession, but we're not having enough money" (P25)

"You would have to have discussions with general ophthalmic services about what we can claim for and that type of thing as well I suppose would have to be looked at." (P15)

"In Scotland we can't do that. We can't…we provide an NHS… Now we've had NHS funded eye tests for so long people expect it. So if you turn around and said no, we're now a private business and it's going to cost you £120 to have your eye test, would you keep your customers, your clients? So as a business owner it's horrible. It's a horrible situation to be in. We want to be healthcare provider and give the best to our patients, but you can only survive if you sell glasses. So you have to balance … (P26)

The adoption of AI technologies has the benefit of reducing the ***period of uncertainty and patient stress*** (4/18), particularly by increasing the accuracy of diagnosis:

> *"if something comes up, looking in to it more and not just telling your patient, this is maybe something, and worrying them for no reason. So it's just being careful when each image is maybe being looked at and…yeah, to avoid any unnecessary, kind of, worry as well." (P13)*

> *"Increased accuracy would be better. If it can be done in real time that would be better. If it can be done in a practice or the location that the image is captured would be better. If it can be done in a way that the patient gets the result in a supportive manner that they can have their questions answered would be better." (P2)*

> *"I think it's the same with if we have an OCT image which AI has confirmed as showing changes which require further investigation, then that supports you in your wish to then refer the patient to the hospital." (P7)*

Campbell [2021] emphasises the ***importance of sustainability***, "*Even after effectiveness has been demonstrated and the community wants to adopt the technology, there should be a sustainable strategy for the technology to be put into practice, scaled to need, and maintained and updated long-term*." (p 4). This aspect was highlighted by six of the optometrists. Some suggested that the government should support not just acquisition of new equipment, but also the organisational procedures and systems to support this work and the extra time spent by optometrists[29]:

> ***"****In Scotland, the funding from Scottish Government would have to match the amount of time that's actually being spent to use this sort of equipment [the AI equipment] to aid with diagnosis" (P6)*

Two of the interviewed optometrists considered that, without a financial reward, some optometrists may be reluctant to take on new roles:

> *"But then again you come back to this idea of are you being rewarded financially, so a lot of optometrists are not happy that, you know, they started off just doing a sort of basic eye test, and now there's all these bits and extra pieces, sort of all this responsibility landing on them for about the same amount of money … and the same amount of chair time people talk about, and should they actually be, you know, they're an allied health professional, but it feels like it's becoming more and more focused on the sort of healthcare side and the acute emergency eye side of it. There's definitely that worry from certain people." (P6)*

P24 explained that the contract that optometrists have with NHS encourages them to take more responsibilities in healthcare compared with their colleagues in England:

> *"I would say that that is less common in Scotland now [to have optometrists who do not want to involve in healthcare] because we've been doing this sort of work more so than in England, for a long time now. So, I think there are fewer optometrists like that in Scotland than there would be in England …. So, we have a different NHS contract in Scotland compared to England. The contract with the NHS that we have in Scotland empowers us more, pays us more, pays us to do some monitoring of conditions. There's, we have paid training here in Scotland that we don't have in England. So, there's a budget for training and developing optometrists." (P24)*

Moreover, P24 also explained that optometrists are more likely to take on new roles in Scotland since the standard of education is higher here, due to more ability requirements and higher-level tests they must pass to remain qualified to practice:

[29] Support needs to be continued to sustain, maintain and renew the organisation and systems, equipment and training.

"if you want to work in Scotland, you have to pass an exam to prove that you're capable of working in Scotland if you come from England. So, there are more stringent requirements in terms of your ability to do the eye health stuff … because the requirements are more stringent. So, yes, there is funding and training, but the requirements are more stringent. So, to perform an eye exam in Scotland compared to one in England is more detailed. A Scottish NHS eye exam is better than an English NHS eye exam; it includes more equipment, it includes more tests, and it just is a better quality of eye exam.

So, when you work in that environment for a while you get better. So, the environment here is a higher standard of optometry and so gradually people's skills, if they're good, then they get better and if they're not good then hopefully they get dragged up to that standard. So, the overall average standard in Scotland is higher than in England." (P24)

However, P26 thinks that, in spite of the NHS funding some extra services (e.g., taking fundus photographs), it does not pay enough to encourage optometrists to provide all services they may be expected and able to provide:

"So it's a hard one because you have to sell glasses to keep a business. But a lot of the secondary care stuff doesn't pay for your time. So you don't get paid enough from the NHS to provide these services to be able to do that solely. So when you're managing your diary you have to consider options on who's in, how many points do you allocate to health? How many do you allocate to children? How many do you allocate to somebody likely to buy glasses? It's a very tricky balance to pull off. So in England, where the eye test is not free, most of them are going private. So as an optometrist they would separate and just go private and don't do any NHS work, which is very much the trend currently, especially after COVID." (P26)

On the same line, the optometrist P25 explains that optometrists are moving more to healthcare services, working harder while getting the same income:

"The NHS GOS fee hasn't changed very much at all, so optometrists are working harder and doing more for less than they were, and in order to try and balance the books on that, you'll find that some optometrists are forced to discuss other subjects such as like contact lenses and spectacle…the different types of spectacle lenses that the person might wish to choose in order to try and fund for the staff that are out on the shop floor.

So there's…it's an interesting dynamic, being in an optometry practice where we're moving more and more clinical and we're embracing more and more clinical tests, but we're not being funded for it yet." (P25)

Therefore, although all the interviewed ophthalmologists thought that optometrists can and should take on new roles, they commented (3/5) that some of them would be enthusiastic to do so, while others may not want to embrace any additional roles due to the financial implications that could have on reducing their dispensing of refractive corrections.

The idea of a specific audit and tailored training came from an optometrist:

"if you are going to utilise this, you're auditing it and then you're actually able to follow through and establish whether there was accurate usage of it. And it may well be that tailoring training dependent on the findings of these audits." (P18)

Both optometrists (6/18) and ophthalmologists (3/5) mentioned ***standardisation*** in terms of using the same devices for taking images, software applications that "talk to each other" or using the same system:

"There might be a technology issue and a standard that, you know...and can you...there are so many different types of devices, how easy is it to tag it on to...and you know…different manufacturers, different proprietary software. So everyone has

got to be equally valid when they use this type of software. I think that fact that we have got so many different systems that are independent, I think that is going to be a challenge getting things to work for everyone." (P16)

Additional information should accompany the images and that must be standard, too:

"Again, could we put it into age range, because quite often age range and underlying systemic disease is where the test times are different? It may well be under 16s are normally tested every year, 16 to 60 are normally every two years, so it could be based on an age bracket. We could bracket the patients, that would maybe standardise things a wee bit better." (P10)

As part of tele-ophthalmology, ***remote consultations*** [Li *et al.* 2020, 2021] were adopted in many countries, including Scotland [Wherton & Greenhalgh 2020], particularly during the Covid-19 pandemic, and both optometrists (4/18) and ophthalmologists (5/5) recognised their merits:

"it's often the case if you get it looked at and triaged around the time that you have the problem, they don't necessarily have to go into Secondary Care. But obviously during COVID, they were doing very clever things on retinal detachments and things that were being diagnosed over the phone using telemedicine, and I think for certain things, it's fantastic." (P5)

"I could see it being really useful for… to be able to bring eye health screening to much more remote locations." (P28)

One of the optometrists highlighted the risks of virtual appointments:

"I think the risk, which I always explain to patients, in a virtual appointment is that it is easy to miss subtle changes in ocular pathology." (P22, ophthalmologist)

However, ophthalmologists emphasised the benefits of remote consultations, particularly the fact that the patient can stay easily in touch with the clinician who can detect any 'gross alteration":

"But the benefits are at least timeously we can be getting in touch with the patient and either having a chat with them or reviewing images just to make sure that there is no gross alteration." (P22, ophthalmologist)

In addition, remote consultations, can reduce the burden on secondary care through triage:

"I think the benefits of it would be definitely trying to reduce the number of patients that need to be seen in the hospital – that's good." (P23, ophthalmologist)

Moreover, it can be more convenient for the patient as they may not need to travel:

"it might save the patient journey coming into the hospital … I think it's certainly in… maybe not in Edinburgh so much, but in remote locations that's definitely the way forward – bring the images to the doctor instead of the whole patient." (P23, ophthalmologist).

Some optometrists (5/18) commented that they do not have enough information about SCONe to expand on their answers:

"But again I've probably not seen enough about how the current intentions are, what the current plans are to realise benefits to then qualify what could be done to make it better." (P2)

A number of questions were raised about the SCONe project (though some optometrists (5/18) commented that they do not have enough information about SCONe to expand on their answers (see Appendix E page 57). These questions referred to: *informing the patient and taking their consent; taking images and uploading to the system/national collection; when and how the AI tools are supposed to be used in practice; how the contact with the patient will be changed by the use of AI tools*. The interviewed optometrists suggested that SCONe needs to:

"raise awareness in what SCONe is doing and things like that. I think if that was the case and the information was more readily available or was made compulsory across the board, I think that would certainly make things much easier. (P10)

Certainly, SCONe needs to make its plans more transparent in order to get more consistent contribution from the stakeholders:

"But again I've probably not seen enough about how the current intentions are, what the current plans are to realise benefits to then qualify what could be done to make it better. Detecting progression of wet AMD is wonderful but I don't know enough about when that would be done, how it would be done and how it would be implemented to probably offer much further guidance." (P2)

2.3 Interview summary, highlights and limitations

Support for SCONe: This study revealed that optometrists and ophthalmologists support SCONe's plan of building a national retinal image research repository and would be happy to use AI-powered decision-support assistants in their practice. As mentioned before this positive response is not surprising since most of our interviewees were recruited via SCONe contacts. A common perception was that patients would agree for their data to be used, provided they are assured their data is properly used[30]. However, this conclusion should be taken with caution as we were not able to interview patients.

Optometrists and ophthalmologists identified ways in which SCONe's research data archive could enhance medical research and its application:

- enable the discovery of correlations between phenotypical data, lifestyle data and socio-geographical data and the eye disease risks[31],
- reduce the time to 'translate' research into practice.

Improved care: Most of the optometrists interviewed also recognised the potential of these new technologies to improve patient care in ways that went beyond (and are not immediately supported by) SCONe's research goals. They hoped these technologies would yield the following benefits:

- faster and easier collaboration between optometrists and ophthalmologists,
- continued tracking of patient data when they moved between optometrists[32],
- less duplication of work,
- reduced health inequalities between different regions and social groups, and
- enhanced collective learning and longer-term management of the patients.

Many of these proposed improvements go beyond SCONe's current plans – though they may be addressed through contemporary developments in NHS Scotland, such as OpenEyes[22], in relation to electronic patient records and population health planning.

In the long term, optometrists considered that research benefits would include earlier detection of diseases due to an increase of accuracy of diagnosis and increased efficiency in reviewing images. Disease progress and risk prediction should also receive researchers' attention. The diseases which need research prioritisations were identified as AMD, glaucoma, and diabetic retinopathy. Campbell *et al*. [2021] identify AMD and diabetic retinopathy diagnostic decisions as having AI decision-

[30] SCONe will upload historic data collected previously by optometrists and therefore non-consented data.
[31] Such linking with other data requires ethical and data-protection approval and may be restricted to NHS staff.
[32] Such access would require adequate governance and Caldicott compliance.

support ready to be transferred from research to practice. They see difficulties with glaucoma diagnosis and suggest that there AI may help with treatment planning.

Data-sharing: Concerns were raised regarding the data sharing and use. The main concerns were related to the current technological limitations and costs of new needed equipment, the quality of images and the difficulties around transferring images and lack of standards. With present systems (delivered via the SCI gateway), taking and uploading images is time consuming, and extra time is required for discussion with patients about data sharing and use.

Education and training: Both optometrists and ophthalmologists recognised that the use of shared data and applying AI tools in community optometry would require education for optometrists and ophthalmologists, (also for the wider public). This education needs to meet national standards and the accreditation system should eventually include those. The delivery of this training should be carefully planned and should be provided flexibly, taking into account that optometrists are extremely busy. Both optometrists and ophthalmologists felt that the use of AI tools could enhance the health professional role of community optometry. Conversely, they were also concerned about the possibility that use of these tools might prevent the development of or lead to erosion of clinical diagnostic skills, reduce in-person contact with the patient and might increase their workload. They also worried about the time needed for training.

Business pressures and new roles: The majority of the interviewed optometrists and ophthalmologists highlighted the commercial pressures facing community optometry which may run counter to taking on more roles and responsibilities. Prescribing and dispensing refractive correction (spectacles or contact lenses) to correct the vision of patients with refractive errors is a vital service delivered by optometrists. However, optometrists in Scotland also play a crucial healthcare role, diagnosing and managing many eye diseases and some systemic conditions, either independently or in collaboration with GPs and secondary care services. The balance between these roles is varied and is changing as optometrists take on more responsibilities. Though many of our respondents were keen to use AI decision support assistants and take on new roles, they noted that for economic reasons some optometrists might be forced to focus on refractive error correction and selling glasses since the funding for healthcare procedures does not yet match the time and effort required. However, some optometrists expected that adopting AI decision support could result in increased efficiency and decrease their workload and stress. Additionally, several optometrists considered that using new technology would contribute to their reputation and make them be viewed as being up to date.

Service innovation: Our most interesting findings are related to service innovation. Currently, most optometrists feel that they work in isolation and they hope that the national archive would help increase collaboration with their colleagues and with secondary care. Therefore, they perceived that the national ocular image collection could lead to collective learning and collaborative management of the patients. They also brought the idea that this collection could support tracking the patients (as the collection may allow optometrists to access patient's history and monitor disease progression) particularly when patients move between optometry practices. This is

perhaps a matter that might be addressed through the OpenEyes initiative[33] rather than the SCONe research archive.

Optometrists expect improvements in their relationships with secondary care. Thus, they expect better communication and feedback from ophthalmologists on what happened to their patients. On the other hand, ophthalmologists think that their relationships with optometrists are quite good. Instead, they proposed hubs where optometrists take images to resolve the problems arising from incompatibilities between the devices and software in use across practices.

Improved collaboration and tele-ophthalmology: The idea of jointly developing treatment plans by optometrists working in hospitals and ophthalmologists was brought into discussion by both optometrists and ophthalmologists. An ophthalmologist proposed that more optometrists should work in hospitals with ophthalmologists, but also more optometrists should visit hospitals and be trained to take new roles. In addition, the idea of remote consultations involving optometrists and ophthalmologists was suggested by one ophthalmologist and one optometrist. In fact, trials of tele-ophthalmology consultations involving optometrist-ophthalmologist pairs reviewing cases and considering relevant ocular images are already underway in Scotland [Ghazala *et al.* 2020, Poyser *et al.* 2019, Wherton & Greenhalgh 2020] and more widely [Greenhaigh *et al.* 2021, Li *et al.* 2020, 2021].

The interviewed optometrists and ophthalmologists recognised the benefits of remote consultations. In spite of some potential risks, the interviewees considered that these can allow the patient to have quicker access to experts and obviate the risk of eye damage from delays in treatment. In addition, remote consultations help reduce the burden on secondary care though triage and may reduce the number of patients' journeys to the hospital. More about these benefits may be unveiled through new investigations which could include optometrists and ophthalmologists who have had the chance to experience remote consultations/tele-ophthalmology.

Changing responsibilities: Though the interviewed optometrists and ophthalmologists considered that more roles should be transferred to community optometrists, it was clearly emphasised that this transfer should be carefully analysed. That analysis should take into account the patient, but also the optometrists' interests. This requires more in-depth studies which have to include patients, more optometrists (particularly those working in multiples) and ophthalmologists and other stakeholders.

Optometrists think that the adoption of AI tools would reduce optometrists' uncertainty when making diagnoses and deciding whether a referral should happen. This would reduce patient stress resultant from unnecessary referrals, hence improving patient care. That will come with the increase of accuracy which will reduce the time for decision and increase patients' confidence. It also reduces the triage load on secondary care services.

Adopting standards: Another idea which fell within service innovation was standardisation. That was brought into discussion by both optometrists and ophthalmologists and included the standardisation of devices and software

[33] https://openeyes.apperta.org/news/2020/12/16/scottish-national-eyecare-service-adopts-openeyes.html

applications, but also of the standardisation of the information that should accompany a patient's image (e.g., age, underlying systemic disease).

Study limitations: The main limitation of our study was that most of the optometrists interviewed were recruited through SCONe, so they were likely to be people more interested in their profession and keen to keep up to date with the new developments. Also, all but four optometrists were working in independent practices, and as a result they felt they were able to exercise more autonomy over how they allocated their time than those working for multiples. Thereby they were able to devote more time for expanded secondary care roles.

Further studies involving more diverse interviewees (i.e., covering various practice types, sizes and locations) will be needed to understand how to implement each service innovation in relation to the practice type, size and location (e.g., rural versus urban) and how public policy and support might best be configured to ensure sustainable provision and widespread access to enhanced community secondary care. Such further studies should include other stakeholders, including patients, other members of provider teams, and NHS managers and planners. Eventually, such studies should encompass the aspects described by Campbell *et al.* [2021] p6: "*Such prospective implementation science clinical-trial design requires multi-disciplinary expertise from clinicians, health economists, human-computer interaction experts and AI software engineers. Study designs need to be tailored to address the context specific technical, economic, cultural and logistical barriers to implementation.*"

3 Conclusions and future work

The OPS study despite its limited resources and short duration has nevertheless identified significant issues and questions that warrant further investigation. We offer suggestions as to how they may be addressed.

3.1 Findings and their limitations

The analysis of the interviews (18 optometrists and 5 ophthalmologists, all but one currently active in providing ocular healthcare) revealed universal support for innovations based on collaborative use of images and cautious deployment of AI decision support. The bias in recruitment of respondents toward actors (optometrists and ophthalmologists) linked to the SCONe project may have led to an overestimate of the prevalence of this support. Exploring views of other stakeholders, e.g., patients and healthcare administrators and a wider range of ophthalmologists and optometrists in a future study may reveal different or stronger concerns. We highlight the following observations from the detailed analysis presented in section 2.2.

1. Whilst willing to share their images of their patients' eyes, there was concern over **technical difficulties**, **lack of standardisation** and the **effort involved**.
2. Various ways of **collaborating** over the use of ocular images were envisaged. Whilst the SCONe national archive will solve the technical and organisational issues its permitted uses will not include those collaborations, e.g., access to a patient's images when they move between optometry practices. Work underway in the OpenEyes initiative should address this[22]. As our interviewees did not seem to be aware of the OpenEyes initiative, it would be beneficial if NHS/NES advertised and explained this initiative to their optometry and ophthalmology communities.

3. An expanded health professional role of community optometry services in diagnosis and management of ocular diseases with new technologies has significant potential health and patient benefits but may be in tension with commercial competitive pressures. Attention needs to be given to establishing a **supportive professional and financial environment to ensure widespread and sustainable provision**.

3.2 Residual and new questions

The following questions need to be resolved before the potential innovations can be implemented as widely adopted and sustainable innovations in ocular healthcare across Scotland, or even locally in Edinburgh and the Lothians.

1. What level of standardisation of ocular images exists in practice at present in Scotland, how stable is it and how can it be improved? The DICOM supplement standards for ocular images are well-defined and have been around for a long time with few amendments. The extent to which the current equipment deployed in optometry practices and ophthalmology centres (and its supporting software) has consistently adopted these standards is unknown. Similarly, it is unclear whether purchases and policies are converging or diverging.
2. In Scotland, what are the currently available systems and tools enabling image transfer and shared access to images in a confidential setting? How can they be improved? To what extent do they handle the linking to other data about a patient? SCONe, OpenEyes and work to introduce digital patient records could collaborate to minimise the '*infrastructure work'* falling on optometrists, patients and their supporters [Gui & Chen 2019].
3. What are the available and approved tools to support pseudonymisation of images and associated data?[34] What would be required to enable their *sustainable* deployment for a sufficient portion of the data to be handled by SCONe (and OpenEyes?), for education and optometry-optometry and optometry-ophthalmology collaboration? What steps would be needed to get those responsible for the ethical governance such as the Caldicott guardians to trust the work of these tools, as human inspection of the volumes of image and related data involved is infeasible? What oversight regime would govern such processes and the rare reversal requests?

3.3 Future work

During this short study, a wide array of issues has been flagged by respondents and emerged from our analysis that merit further investigation.

1. An immediate priority should be an extended study to address the scope for enhancing community optometry service with digital technologies. This work would need to capture the full range of contexts for community optometry, patient perspectives, ophthalmologists and also regulators, funders and technology vendors. The follow-on study (or related specific studies) should address a range of drivers and barriers for such service enhancement including funding and commercial pressures, training and accreditation requirements, information governance, data exchange standards and

[34] This has been solved in other medical DICOM imaging communities. For example, https://sourceforge.net/projects/privacyguard/ is compliant with the Scottish system and allows for servers to automate a process with specified rule sets.

infrastructure, the design and implementation of change programmes to prepare for and sustain eye healthcare service innovations [Valikodath *et al*. 2021]. Standardisation efforts will need to align with similar standardisation programmes internationally.

2. Further studies may be needed to explore the scope for improving management of particular chronic eye conditions. Management of dry macular degeneration (p22) is already a SCONe priority and the subject of much research elsewhere. To reduce potential delays in translating research success into effective and widely adopted implementation across Scotland representatives of the professional and managerial groups involved as well as patients and their supporters should begin to design and plan the changes necessary.

3. Additional research may be needed to support the scientific development and exploitation of the SCONe project. A national repository of ocular images has significant potential for accelerating the validation and tuning of working AI decision support assistants for the Scottish cohort of patients. At present ophthalmology-department image products will not be transferred to that archive. Their inclusion should be considered to improve the archive's potential as a source of discoveries correlating early observations to later outcomes – though in many cases fundus images taken by optometrists will continue for sufficient time. The use of this resource, together with linked data from other NHS and social services sources will be carefully regulated. Within such regulation, it may be possible to improve the support for AI and other researchers, by developing frameworks that facilitate their access. It would give them good control over the computational power needed in the safe haven[35] and help them extract their result data with full compliance with any conditions imposed. A study to investigate the socio-technical issues and the feasibility of an acceptable but useful framework would have the potential for long-term payoffs, not just in Scotland. From the computing point of view, it should simplify the use of scalable data analytics with mappings that are adapted as the available platforms evolve [Filgueira *et al.* 2021]. That would include serverless computing embedded in suitable security with pervasive persistent protected provenance to support governance [Klampanos *et al.* 2020] and automated assistance with rule compliance [Zhao *et al.* 2021].

4. As this line of medical research develops, rarer conditions will be tackled - particularly when investigating genetic factors and aetiology. Then, to access sufficient occurrences of a disease, more samples will be needed than can be found in one national collection. Consequently, requirements will emerge for sharing information between such collections of de-identified ocular image data. That will require agreements on interchange standards and the protocols for conducting such interchanges and the use of the results. Establishing an international alliance to facilitate well-regulated collaborative pooling of such research resources would be a valuable long-term objective. Scotland could provide leadership in forming that alliance[36].

[35] A safe haven provides controlled access to those who have been granted permission to selected data using approved software [Robertson *et al.* 2016].
[36] As ROE did initiating a similar alliance organising the sharing of astrophysics images for research.

The OPS study has exposed many questions at a time of rapid advances in ocular healthcare. The potential of retinal-image repositories and the AI decision support to improve eye healthcare and to help the professionals who deliver it is evident. To reduce the risk of delays in delivering those benefits widely, follow-up investigations should begin and actively engage *all* stakeholders. Scotland is in a strong position because its well-established optometry profession, ophthalmology research, AI research, medical informatics and NHS Scotland are already working together. *Acting now will maintain that strength*.

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Appendix A : Abbreviations and definitions

Table 2: Abbreviations and definitions

term	definition
AI	**Artificial Intelligence** digital systems that perform inference and reasoning
AI decision support aids	AI systems that help a professional spot significant signals latent in data and interpret them. This is needed as the volumes of data increase. However, it risks incorrect interpretations so that the final judgement remains with the professional. See page 9.
AMD	**Age-Related Macular Degeneration** is an eye disease that can begin at any age, but usually develops after age 60. This eye condition progressively destroys the macula, which is the central portion of the retina that helps with focus. There are two variants: **Dry AMD**: a gradual deterioration of the macula, as the retinal cells die off and are not renewed. **Wet AMD**: abnormal blood vessels grow into the macula, they leak blood or fluid resulting in loss of vision. (see https://www.macularsociety.org/macular-disease/macular-conditions/ and page 8)
CET	**Certificate of Education and Training**
Choroid	The pigmented vascular layer of the eyeball between the retina and the sclera.
College of Optometrists	The College is the professional body for optometrists. It qualifies the profession and delivers the guidance, development and training to ensure optometrists provide the best possible care. We recognise excellence through the College's affixes, It builds the evidence base for optometry, and raises awareness of the profession with the public, commissioners, and health care professionals. https://www.college-optometrists.org/the-college/about-us.html
CPD	**Continuous Professional Development**
DALY	**Disability-adjusted life year** is a measure of overall disease burden, expressed as the number of years lost due to ill-health, disability or early death.
(Digital) Archive	**A curated collection of digital items** with arrangements in place for long-term sustainability, quality control and governance, easy access for approved purposes (by humans and software), protection, and aspiring to achieve FAIR
DR	**Diabetic retinopathy** a disease affecting ~25% of those suffering from diabetes (see page 7)
e-Learning	Self-managed education using materials and course interactions provided via the internet
Glaucoma	A group of conditions often accompanied by increased pressure in the eye (see page 7)
FAIR	**Findable, Accessible, Interoperable and Repeatable**
FAQ	**Frequently Asked Questions**, usually accessed via the internet a way of packaging advice and information around the questions people often ask to reduce the load on support staff
Fundus	The inside, back surface of the eye (see page 8)
Fundus camera	Produces a coloured image of the fundus (see page 8)
GOC	**General Optic Council** The framework for the conduct of ocular healthcare in the UK (see page 6)
GOS	**General Optometry Services** are the arrangements by the Scottish Government for providing optometry services throughout Scotland [Scottish Government 2018]

	https://www.isdscotland.org/health-topics/eye-care/general-ophthalmic-services/
GP	**General Practitioner** a healthcare doctor who provides primary care as part of the NHS in Scotland, predominantly with those patients registered with their practice
IoT	**Internet of Things** the many devices, such as wearable digital instruments and actuators, that are capable of being accessed via the internet and/or receive control signals via the internet.
Macula	An oval area surrounding the fovea near the centre of the retina in the eye, which is the region of keenest vision.
Multiple	A chain of optometry practices, e.g., Boots, Specsavers & Vision Express.
NES	**NHS Education for Scotland** – the education and training body for NHS Scotland
NESGAT	**(NES Glaucoma Award Training)** is a programme of accredited education and training in glaucoma management, delivered by NES Optometry
NHS	**National Health Service** e.g., in Scotland https://www.scot.nhs.uk/about-nhs-scotland/
OCT	**Optical Coherence Tomography** generates cross-sectional images of structures within the eye at a high-resolution (see page 8)
OCT Angiography	Laser imaging of the vascular structure and blood movement in the eye.
Optometry Scotland	The representative body for Optometrists and Dispensing Opticians in Scotland https://www.optometryscotland.org.uk/
OPS	**Optometry Pilot Study** conducting research reported here
Primary care	The first organisation / professionals dealing with an individual's healthcare, e.g., GPs for general health, dentists for dental care and optometrists for ocular conditions. They may all refer patients to specialists in secondary healthcare when necessary.
R&D	**Research and Development** the conduct of work to test hypotheses and to generate knowledge, and the conduct of work to convert such knowledge into deployable, usable and sustainable systems.
Remote consultations	A patient consultation with an optometrist or ophthalmologist across a telephone or video link, in contrast to an in-person consultation
Retina	The layer at the back of the eyeball that contains cells sensitive to light, which trigger nerve impulses that pass via the optic nerve to the brain, where a visual image is formed.
SCI Gateway	SCI Gateway is the national product in NHS Scotland for the electronic exchange of clinical information – such as referral letters and discharge documents – between Primary and Secondary Care. https://www.sci.scot.nhs.uk/products/gateway/gate_desc.htm
Scotoma	A partial loss of vision or blind spot in an otherwise normal visual field
SCONe	SCONe is an initiative to collect, classify and curate retinal images captured by optometrists across Scotland to create a retinal imaging research repository. Early work will include the development of automated techniques to evaluate the onset and prediction of progression of AMD." https://www.ed.ac.uk/clinical-sciences/ophthalmology/scone/about-scone
Secondary care	Provides specialist healthcare capable of treating conditions not treatable in primary care, e.g., hospitals
Sclera	The white outer layer of the eyeball. At the front of the eye it is continuous with the cornea.

Teach and Treat	*NES has established regional teach and treat clinics to give community optometrists the opportunity to manage and treat patients under the close personal supervision of an ophthalmologist, while at the same time providing first class patient care for patients presenting with acute eye problems. The training is designed to increase the optometrist's exposure to acute conditions and work through the differential diagnosis to a management plan agreed with the Ophthalmologist.*
Tele-ophthalmology	In a general context this refers to any method by which an ophthalmologist can make decisions about a remote patient. Here it means arrangements where optometrists in their practice take professional images which they then share with an ophthalmologist at a referral centre or a live video consultation where the optometrist performs an eye exam using a video slit lamp, whilst an ophthalmologist is linked in via video call and can collaboratively examine and manage the patient in real time. They jointly form a decision on the appropriate treatment thereby reducing the number of unnecessary referrals and accelerating urgent decisions. See Greenhaigh *et al.* 2021 for a full discussion,
Video-conferencing	Using technologies such as Zoom, which transmit video across networks and facilitate viewing, control and interaction, individuals communicate orally and visually in a virtual meeting.

Appendix B : Script and formalities for optometrists' interviews

This appendix contains the final version of the script used for conducting interviews with optometrists. This is the eighth version; it was revised several times particularly after the early interviews in the light of experience. It was used as a guide with variations to enable follow up and to adapt to an interviewee's interests and expertise. This appendix also contains the information sheet and consent form used to comply with the formal ethical approval granted by the School of Informatics, University of Edinburgh.

Appendix A.1 : Script for optometry interviews

Here we show the background information offered to inform each interviewee about what the next part of the interview is about or what the next question is about. We then state the information sought and propose a script to *prompt* the interviewer. The script will not be followed verbatim. Three aspects of the SCONe approach are discussed:

1. **DS**: Data sharing
2. **AI**: AI-based *aids* to image interpretation and decision making
3. **LT**: A research resource supporting an open-ended set of investigative opportunities with potential biomedical and healthcare benefits in the Long Term.

Each aspect should proceed from current translation of available research to visions of potential extensions. The positive benefits should be explored and then worries, threats and issues should be considered. OPS's raison d'être is to expose threats to SCONe's sustainability and applicability in order to propose mitigations, hence issues must be included. Conversely, clarifying potential benefits and hopes which can be enhanced leads to opportunities for improving SCONe's impact and accelerating its uptake. The balance should be dynamically adjusted during each interview.

Interview script begins[37]

Orienting the interview: Thank you for agreeing to help with our study. We are trying to help SCONe*. They will improve diagnostic precision and ophthalmic services by making the better use of retinal-images, by developing AI tools to help you interpret those images and improving support for **community** optometrists. We want to hear your views on their approach and to gather your suggestions. With your help we will help them, and those that use the retinal images as a research resource, help you, your patients and your optometry practice.

Data sharing is currently not practiced for retinal images obtained in optometry practices. Typically, the images remain locally stored unless sent to a hospital when a patient is referred. These images may be lost when devices, systems or storage media are replaced. SCONe* plans to gather these images under proper regulation and protection to enable two kinds of study that are otherwise not possible. (1)

[37] These scripts are shown with the colour changes, highlighting, etc. to help the interviewer (AC) navigate the script during an interview. Similarly, footnotes in the scripts provide information the interviewer may want to use.

longitudinal studies to better understand how eye diseases develop and (2) correlations between patients. This has the potential to reveal ways of improving diagnosis and treatment of eye diseases. That may result in additions to optometrists' training or to new AI-based features in the software supporting work in your practice.

*SCONe is establishing a means of pooling Scottish optometry digital-image data in a safe haven for research and to enable advice to flow to optometrists to improve patient care.

DS: Data sharing

Scene setting

Retinal images and related data have been collected during a patient's consultation and archived. However, these data cannot currently be used for research. SCONe[38] will establish a long-term research archive of this data (compliant with Caldicott and GDPR) to make it accessible to *approved* researchers for *approved* purposes. During this interview, we would like to find out what are your perceptions/opinions about the benefits and challenges related to this.

Modern medical research seeks to understand the causes and progression of disease by looking at data from large numbers of patients or over long time periods or both. The SCONe research archive will enable the discovery of significant correlations and risk factors.

QDS1: How do you feel about data from your practice being used by SCONe?
→[39]Can you tell me more about difficulties you foresee?
What do you think your patients would feel about it?
→ What difficulties do you anticipate? Which of them are the most troublesome?
Will it be difficult to explain to your patients how their data may be used in SCONe?
→ What difficulties do you anticipate? What is most important to explain?

QDS2: What do you hope this development of a shared research collection will do for you and your patients?
Do you anticipate any problems resulting from this data sharing and the developments it will enable?
How should we increase the benefits and reduce the downsides?

AI: AI-enabled methods

Scene setting

Artificial Intelligence (AI) tools are being used to look for patterns in medical record collections to identify risk factors for diseases and to support feature recognition (e.g., in screening). These methods can potentially help with diagnosis and treatment of eye problems, as well as with alerts on disease progression. Any deployed AI has gone through rigorous testing to prove its safety and benefits, however, there is a residual risk of false positives causing unnecessary stress and work, and false negatives delaying treatment.

[38] Located in the University of Edinburgh (Medical sciences, Ophthalmology and Usher Institute), SCONe is establishing a means of pooling Scottish optometry digital-image data in a safe haven for research and to enable advice to flow to optometrists to improve patient care.
[39] The arrow indicates a possible follow up question which will be used if mor detail is needed and there is time.

QAI1: If AI was assisting you as you diagnose retinal conditions using fundus photographs:
would you want to use it?

More scene setting
Optical Coherence Tomography (OCT) builds a 3D representation of the retina. Research is being conducted into developing and deploying sophisticated algorithms that help you detect or measure significant features in an image, such as fluid behind the retina or retinal thickness.

QAI2: If computer-aided detection was available to help you diagnose retinal conditions using OCT would you want to use it?

QAI3: Considering such AI tools to help you look after your patients:
Would you feel confident using them?
In what ways do you hope they will help your work in the future?
Do you have any concerns about what they may lead to?
How should we increase the benefits and reduce the downsides?

LT: Research with long-term benefits

Scene setting
Though SCONe is focused in the short-term on predicting wet AMD progression from OCT scans[40], it will develop a long-term and comprehensive collection of retinal images that could be used for example for diabetic retinopathy screening (currently conducted in hospitals)[41] and for research

QLT1: What are the benefits of establishing a research collection of retinal images for the whole of Scotland?
What additional patient-care methods do you hope that research will yield?
Are there downsides that we should avoid?
How should we increase the benefits and reduce the downsides?

Education toward acceptance of data sharing and AI tools(?)

Scene setting
Obviously, data sharing and the use of AI tools are quite new for optometrists and there is a need for education related to their acceptance.

QEA1: Have you any requirements or suggestions regarding that education?

Wrap up and thank you

Scene setting
Thank you very much, I have really enjoyed discussing these ideas with you.

Qfinal: Are there any other points you would like to raise about the development of
diagnostic services using digital technologies?

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[40] J. Yim *et al*. *Predicting conversion to wet age-related macular degeneration using deep learning*, Nature Medicine, Vol. 26, June 2020, 802-899. https://www.nature.com/articles/s41591-020-0867-7
[41] Y. Xie *et al*., *Artificial intelligence for teleophthalmology-based diabetic retinopathy screening in a national programme: an economic analysis modelling study*, Lancet Digital Health 2020; 2: e240–49, April 2020. https://www.thelancet.com/journals/landig/article/PIIS2589-7500(20)30060-1/fulltext

Snowball: Can you suggest others who we might interview?

What happens next

The interview has been recorded. We will get that record transcribed taking care to protect your anonymity. We will analyse the transcript and produce a resulting summary, which we will ask you to check. You may delete, add or change anything you wish in the summary. We will then use your results statistically, or carefully anonymised. We will share any publications with you, and you can withdraw your consent for your material to be used at any time.

If you have time, we would like you to fill in all or part of this Post-Interview Questionnaire (probably not given out at the end of the interview).

End of interview script

Appendix A.2 : Information sheet and consent form

Information sheet:

1

Optometry Pilot Study

Participant Information sheet and Consent form

22nd March 2021: Aurora Constantin and Malcolm Atkinson

Participant Information Sheet

Project title:	Optometry Pilot Study (OPS)
Principal investigator:	Prof Robin Williams
Researchers collecting data:	Aurora Constantin, Prof Malcolm Atkinson
Funder (if applicable):	SFC via DDI

This study was certified according to the Informatics Research Ethics Process, RT number 62378. Please take time to read the following information carefully. You should keep this page for your records.

Who are the researchers?

Prof. Robin Williams, Prof. Malcolm Atkinson, Dr Aurora Constantin, Dr Miguel Bernabeu

What is the purpose of the study?

This study is looking at the implications of new technologies for sharing and analysing retinal images for the detection and management of retinopathy by Ophthalmologists and Optometrists. The Scottish Collaborative Optometry-Ophthalmology Network e-research (SCONe) [1] project aims to improve Opticians' diagnostic precision and treatment capability by establishing a framework for sharing and exploiting high-resolution retinal images. It has developed AI techniques to improve the interpretation of those images.

The Optometry Pilot Study is working alongside SCONe to explore the factors that may affect these new services. For example, optometrists may not be familiar with AI and may be unconvinced that it will help them and may be nervous of its impact on their practice or work. Failure to recognise such concerns and requirements risks limiting the rate of adoption – translation from research to practice. OPS combines the medical, sociological and technical viewpoints to conduct a pilot study with local optometrists to better understand such critical issues and to develop ideas about future steps that will help optometrists and their patients. OPS aims to ensure that advances achieved by SCONe are translated into practice.

Why have I been asked to take part?

You were approached by Fiona Buckmaster in her role as SCONe optometrist and agreed that we could contact you about an interview. We believe that you have the experience of

[1] https://www.ed.ac.uk/clinical-sciences/ophthalmology/scone

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Optometry Pilot Study

optometry and its practice in Scotland that will help us pursue the OPS goals outlined above. We hope that you will help us develop a better understanding of the views, concerns and expectations of optometrists. You may be able to correct our inevitable misunderstandings and you may draw our attention to things we have not thought about that are important to you or to the practice of optometry and the care for patients.

Do I have to take part?

No – participation in this study is entirely up to you. You can withdraw from the study at any time, without giving a reason. Your rights will not be affected. If you wish to withdraw, contact the PI, R.Williams@ed.ac.uk. We will stop using your data in any publications or presentations submitted after you have withdrawn consent. However, we will keep copies of your original consent, and of your withdrawal request.

What will happen if I decide to take part?

You will be invited to participate in an interview at a time that suits you where you will be asked a series of question regarding your perception of the benefits and risks of adopting AI to improve ophthalmic services. These are intended to develop ideas through a discussion. You are also invited to raise any topic that we have not included in our questions that you consider important to the sharing of retinal images and related patient data, to the use of AI or to any aspect of the information systems you deal with. If you agree we will invite you to an interview which will last for a maximum 40 minutes (?). This will be a one-off session.

If you have given us permission via Fiona, prior to the interview we will use the information you provided when you joined SCONe and share that with you. After the interview we will analyse the interview recording. We will combine that with prior information to produce an interview summary specific to you. That will be kept confidential between you and the OPS researchers. You will receive a copy of that and before we use it to derive anonymised information will have a chance to correct our errors, make additions or withdraw your consent.

Are there any risks associated with taking part?

There are no significant risks associated with participation.

Are there any benefits from taking part?

An opportunity to engage in discussion about the SCONe plans and to influence them in the light of your experience and to highlight issues you meet in your optometry practice.

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What will happen to the results of this study?

OPS will identify social, organisational and business issues that will be critical for the large-scale role out and longer-term sustainability of the new optometry-opthalmology practices and relationships being pioneered and supported by SCONe. The results of this pilot study will be summarised in published articles, reports and presentations. Quotes or key findings will be anonymised. We will remove any information that could, in our assessment, allow anyone to identify you. With your consent, that anonymised information can also be used for future research. Your data may be archived for a minimum of 6 months.

Data protection and confidentiality.

Your data will be processed in accordance with Data Protection Law. All information collected about you will be kept strictly confidential. Your data will be referred to by a unique participant number rather than by name. Your data will only be viewed by the researcher/research team: Prof Robin Williams, Prof Malcolm Atkinson, Dr Aurora Constantin, and Dr Miguel Bernabeu.

All electronic data will be stored on a password-protected encrypted computer, on the School of Informatics' secure file servers, or on the University's secure encrypted cloud storage services (DataShare, ownCloud, or Sharepoint). Your consent information will be kept separately from your responses in order to minimise risk.

What are my data protection rights?

The University of Edinburgh is a Data Controller for the information you provide. You have the right to access information held about you. Your right of access can be exercised in accordance Data Protection Law. You also have other rights including rights of correction, erasure and objection. For more details, including the right to lodge a complaint with the Information Commissioner's Office, please visit www.ico.org.uk. Questions, comments and requests about your personal data can also be sent to the University Data Protection Officer at dpo@ed.ac.uk.

Who can I contact?

If you have any further questions about the study, please contact the lead researcher, Prof Robin Williams, Email: r.williams@ed.ac.uk. If you wish to make a complaint about the study, please contact inf-ethics@inf.ed.ac.uk. When you contact us, please provide the study title and detail the nature of your complaint.

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Updated information.

If the research project changes in any way, an updated Participant Information Sheet will be made available on https://web.inf.ed.ac.uk/infweb/research/study-updates.

Alternative formats.

To request this document in an alternative format, such as large print or on coloured paper, please contact Aurora Constantin (Email: aurora.constantin@ed.ac.uk)

General information.

For general information about how we use your data, go to: edin.ac/privacy-research

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Consent form:

Participant number:_____

Participant Consent Form

Project title:	Optometry Pilot Study (OPS)
Principal investigator (PI):	Prof. Robin Williams
Researcher:	Dr Aurora Constantin, Prof. Malcolm Atkinson
PI contact details:	R.Williams@ed.ac.uk

Please tick yes or no for each of these statements.

		Yes	No
1.	I confirm that I have read and understood the Participant Information Sheet for the above study, that I have had the opportunity to ask questions, and that any questions I had were answered to my satisfaction.		
2.	I understand that my participation is voluntary, and that I can withdraw at any time without giving a reason. Withdrawing will not affect any of my rights.		
3.	I agree to being audio recorded		
4.	I consent to my anonymised data being used in academic publications and presentations.		
5.	I understand that my anonymised data can be stored for a minimum of two years		
6.	I allow my data to be used in future ethically approved research.		
7.	I agree to take part in this study.		

Name of person giving consent	Date dd/mm/yy	Signature

Name of person taking consent	Date dd/mm/yy	Signature

Appendix C : Script for ophthalmologists' interviews

This script was derived from the optometry interview scripts to focus on ophthalmologists' experience and concerns. This is version 4; it was revised after the first interview with an ophthalmologist.

Interview script begins

Orienting the interview: Thank you for agreeing to help with our study. We are trying to help SCONe. They will improve diagnostic precision and ophthalmic services by making the better use of retinal images, by developing AI tools to help optometrists interpret those images. We need to better understand the working relationship between ophthalmologists in hospitals and optometrists as the primary-care community-based practitioners.

Opening questions: We want to understand what happens when an optometrist refers a patient to you.

OphQOO1: What happens when an optometrist refers a patient to you?

How long does this take?
Do you stay in contact with the referring optometrist?
Do you look at retinal images they send with the referral?
<if yes, then ask, otherwise skip>
What do you think about the quality and relevance of those images?

How well does the current system work?
Is it very variable depending on the optometrist or the condition?
Do you see ways for improving it?

OphQOO2: After the referral how do you progress to condition management?

Are there potential opportunities for involving community optometrists?
This inevitably depends on the condition.
For which conditions is there a good prospect of gaining help from optometrists?

Ophthalmology-Optometry relationship

Scene setting

There are healthcare and commercial pressures influencing future developments in community optometry. These may affect the relationships between ophthalmologists in hospitals and community optometrists in Scotland.

OphQOO3: How do you see those relationships today?

Do you see trends in optometry practice?
Do you see significant variations in optometry practice?

OphQOO4: How do you think that relationship should develop?

What would encourage this?
Should the optometrists take more roles in managing diseases in their patients?
What barriers prevent it happening today?

What would need to be done to make it happen?

<if short of time, then skip data sharing! Go to AI>

Data sharing is currently not practiced for retinal images obtained in optometry practices. We are not sure whether optometrists send useful images when they refer patients to the ophthalmologists.

DS: Data sharing

Scene setting

We are aware that many high-quality images of patients' eyes are collected at centres of ophthalmology expertise, such as the Princess Alexandra Eye Pavilion (**PAEP**). UCL within the Caldicott framework used data from 27 English healthcare trusts to show statistically the increased rate of vision loss through missed appointments due to Covid-19 disruption.

OphQDS1: What are your views on PAEP patients' non-consented images being used for research in a Caldicott approved study, as that is what SCONe sets up for optometry images?

OphQDS2: There are initial trials of tele-ophthalmology in the Scottish NHS.
How would you assess the potential benefits and risks from tele-ophthalmology?
If tele-optometry became more prevalent, what savings would it make and what extra resources would it require in the centres of ophthalmology expertise?

AI: AI-enabled methods

Scene setting

Artificial Intelligence (AI) tools are being used to look for patterns in medical record collections to identify risk factors for diseases and to support feature recognition (e.g., in screening). These methods can potentially *help* with diagnosis and treatment of eye problems, as well as with alerts on disease progression. Any *deployed* AI has gone through rigorous testing to prove its safety and benefits, however, there is a residual risk of false positives causing unnecessary stress and work, and false negatives delaying treatment.

OphQAI: To what extent do you or your team find AI-based aids helpful?
Do you think AI tools should be deployed to *help* optometrists in the community make more accurate referral decisions?
Would this require additional training?
Is there a risk they would become overdependent on such tools?

LT: Research with long-term benefits

Scene setting

Though SCONe is focused on building a repository of patients' retinal images for research; initially, AMD.

OphQLT: What are your views on this undertaking?
How should we increase the benefits and reduce the downsides?
Which long-term research would you prioritise?

Education toward acceptance of data sharing and AI tools(?)

Scene setting

Data sharing and the use of AI tools are quite new for ophthalmologists and optometrists.

OphQE: Have you any suggestions regarding education that might emerge for each of these professions as they prepare to exploit image sharing and AI-powered assistants?

Wrap up and thank you

Scene setting

We hope to do follow on projects. We know there are many professional roles in a centre of ophthalmology expertise like PAEP.

OphQfollow-on: If we want to improve our understanding of centres of expertise in ophthalmology who else (which other roles in the centres) should we also talk to?

Scene setting

Thank you very much, I have really enjoyed discussing these ideas with you.

OphQfinal: Do you have any suggestions for things we should be thinking about or improvements we might investigate (in follow-on projects)?

What happens next

The interview has been recorded. We will get that record transcribed taking care to protect your anonymity. We will analyse the transcript and produce a resulting summary, which we will ask you to check. You may delete, add or change anything you wish in the summary. We will then use your results statistically, or carefully anonymised. We will share any publications with you, and you can withdraw your consent for your material to be used at any time.

If you have time, we would like you to fill in all or part of this Post-Interview Questionnaire (probably not given out at the end of the interview).

End of interview script

Appendix D : OPS advisors

The following table identifies colleagues who we have consulted during the preparation for the project and the conduct of the project. In due course, we will consult them to help us polish this report. In addition, we promised to give each interviewee an opportunity to require revision of any aspect of the report relating to them. Until that consultation has taken place, we ask that the circulation of tis report is minimised to those who need to see it for administrative purposes.

Table 3: OPS panel of expert advisors

Name	Expertise	Role
Dr Areti Manataki	medical Informatics & healthcare social machines	Senior Researcher, School of Informatics and Usher Institute; Now Lecturer in Computer Science, University of St Andrews
Dr Petros Papapanagiotou	Logical AI systems, medical workflows & Scottish medical-image data (PACS) safe haven	**C**hancellor's Fellow in Digital Tech & AI, School of Informatics and Bayes Centre, University of Edinburgh
Prof Rob Procter	medical imaging technologies, including optometry, expertise in xAI (AI systems that can explain their results) and participatory design	Director, Human-Centred Computing Division Faculty Fellow, Alan Turing Institute for Data Science and AI Exchange Professor, Centre for Urban Science and Progress (CUSP)
Dr Jano van Hemert FRSE	Data-intensive research, data science and ocular image capture and use	Director of Research & Data Science, Optos PLC
Dr Kami Vaniea	HCI, ethics and security	Lecturer in Cyber Security and Privacy, School of Informatics, University of Edinburgh
Dr Maria Wolters	Her research focuses on supporting people with chronic illness to live rich and meaningful lives	Reader in Design Informatics, School of Informatics, and Academic Associate, School of Philosophy, Psychology, and Language Sciences, University of Edinburgh, and a Fellow of the Alan Turing Institute for Data Science.

Appendix E : Questions for SCONe to clarify posed by interviewees

Informing the patient and taking their consent

"I think if that was the case and the information was more readily available or was made compulsory across the board, I think that would certainly make things much easier. Something that we could explain to patients, that would be useful, so everybody is giving the patients the same information." (P10)

Taking images and uploading to the system/national collection

I am not sure how we would make timescale-wise easier. Is it something that is just instantly accessible or something that we need to send? Is it something that we need to take the images and then send and that takes time? I am unsure how we could simplify that part of it. I am not sure. (P10)

I think it is going to take quite a long time to do it and I suppose I don't understand how long you are going to get to get any conclusions. If you take longitudinal things that is going to take forever. Are you downloading or uploading images from years going back and used those or what is the quality issues? (P16)

And I think there's also a difference, and I don't know if this has really been considered, between imaging captured in hospital and imaging captured in practice, in that a lot of imaging captured in practice isn't dilated, isn't of the quality that is captured in a hospital or a screening service setting. A lot of it is captured ad hoc, and I just wouldn't want that to cloud the outcomes and the results. If we think of the images we capture from a diabetic screening point of view we make sure they're all dilated, we quality check them before they're done. If it's just a case of hoovering up every photo that's been captured in a practice in a day that's not going to apply to them at all; the quality is going to be massively, massively different, the average quality is going to be massively, massively different. So, I would be interested to hear how the project plans on tackling that aspect of it, or is it only going to be a small subset of people that you're sucking images from. (P2)

And the other thing is, again in the hospital setting, certainly my experience is that you take a very few number of images, and in community you could have a very scattergun approach to lots of captures to the one patient at one time that might generate a huge amount of data of which 80 or 90 per cent of which might be useless. So, I'm very excited to see how it goes but I just don't know quite how it's going to work from a sitting in the high street point of view. (P2)

Like when we've done shared care in the past, we've been able to do it using SCI Gateway, and it's just gone that way, and that was very, very useful for the shared care. But it did mean scanning in a lot of documents, and stuff like that, so it would be…it's about getting it…it's come straight from the existing software, you know, to some sort of online portal, or something, I don't know. I'm not technically minded enough for that one, I don't think. That's the biggest challenge Aurora, it's always…it's all about how do we get these images on to a platform that's transferred easily, and that's not too time consuming. Because I know there's optometrists that don't send their [fields 00:07:24] and photographs and OCTs to the hospital, because it's difficult for them to transfer them on to SCI Gateway to get there in the first place. (P5)

The main thing I think is the time potentially that it could take to actually share the data, so I suppose it brings up the horrible question of any financial element to it, and whether optometrists would expect to be paid for their time in terms of taking…you know, well, it depends how long it's going to take to share the data, or

whether actually there's a way of SCONE just accessing it without the optometrist having to be involved in any sort of admin around it, that would be the main thing that I would see, the amount of time it'll take, and of course the security of it as well, whether it's a secure…obviously I assume it will be a secure sharing platform in the same way that it is for referrals. Obviously, optometrists can share fundus images by SCI Gateway safely, so I'm sure we can set something up that's similar. (P6)

But would they be uploaded over SCI Gateway? Is that how it would be planned to be done? Do you know? It's just thinking this is questions that colleagues might well ask. Somebody who receives the images and then subscribes an identifier to them which is anonymous before they're fi…I don't know how the software will work. Because it's also useful, if you need to back refer it, you've got to pull it back out again. I don't know. (P7)

Sharing it, also, in terms of what means of transport, so how are we sharing it, like, how are we sending it, will we be sending it via email, flash-drive? Will the actual physical hard drives need to be transferred, like, how would it be transferred? (P8)

So, will those things need to be scanned, time involved, all that kind of thing. And then, how would that be transferred across, again, to yourselves, so physical files, or whether it be PDFs, or whatever it might be, how will the things be transferred? So again, it's just largely on the safety of transfer, the people who are receiving it, how confident are we that everything will be stored safely, and used correctly, and patient consent, really, around all of that. So that would be kind of the main kind of…so, anxious, would be the main thing in regards to, like someone…so it's not like, for example, it was NES, for example, which is the National Education of Scotland, which is the optical kind of side of things, which we have an inherent trust in, or Optometry Scotland. (P8)

When and how the AI tools are supposed to be used in practice

Whether it is just researchers who would use it. (P16)

Yeah, I mean, I don't know how you'd do that. I've never shared an OCT scan with anybody. I've shared, like a segment of it, a line scan, you know, a screen-grab of an OCT scan, but I've never shared a full scan with anybody… So if the bandwidth of our internet was really reduced by sharing files, then that would be a problem. But presumably, there's ways around that, I don't really, I don't know enough about the technicalities of it, but that would be a concern. (P4)

And I hope people give it time, because it takes time technically, to amalgamate everything, to do the work, and see what positive outcomes come. I don't know if that really answers your question, but… So I think it will self-promote because I think it could be very powerful. I don't know. Will the database likely be available to community optometry? Will you be able to dial into it and have a look at it, do you think? (P7)

So whether there'd be any element of sanction over it, I don't know. If it's just a question of gathering this is an image, this is what I think it is, I think that would be fine. I don't know. Interesting to see. (P7)

And ideally – again, I don't know how this is all going to work out funding wise, but – it would be great if they were accessible to say, practices or optometrists. Whether there's any cost to that, I don't know.

But I don't know how you've found kind of responses from your side, whether a lot of people are looking to engage or not. (P8)

How the contact with the patient will be changed by the use of AI tools.

Again, because I don't know, kind of, what it looks like, you know, what the patient flow would be like, what sort of instruments we're talking about, how it would be explained

to a patient, how much contact they would have with me versus how much of it is just automated. (P3)

The other thing I suppose would be that SCONe provide packs for the patients. No optometrist is going to want to have to get involved in writing sheets for consent or information explaining to a patient what it's all about, so you would very much need SCONe to be behind that and giving practitioners all of the information that they could then just pass to a patient without involvement...and the patient then has a record and can take it home. (P6)

So, somewhat apprehensive, until you kind of dig deeper into who, what the SCONe project is, who's involved in the project. Obviously, GDPR is always a big kind of concern when it comes to patient data, and sharing that with external organisations, essentially, without, or once, you'd have to seek individual patients' consent for that. (P8)